Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

The terms training manual (TRAMAN) and nonresident training course (NRTC) are now the terms used to describe Navy nonresident training program materials. Specifically, a TRAMAN includes a rate training manual (RTM), officer text (OT), single subject training manual (SSTM), or modular single or multiple subject training manual (MODULE); and an NRTC includes nonresident career course (NRCC), officer correspondence course (OCC), enlisted correspondence course (ECC), or combination thereof.

Although the words "he," "him," and "his" are used sparingly in this manual to enhance communication, they are not intended to be gender driven nor to affront or discriminate against anyone reading this text.

Naval Education And Training Program Management Support Activity

UTILITIESMAN 2

NAVEDTRA 10662

DEPARTMENT OF THE NAVY ★ CHIEF OF NAVAL EDUC AND TNG ★

1990 Edition Prepared by
UTCS Junior D. Sims

PREFACE

The ultimate purpose of training naval personnel is to produce a combatant Navy which can ensure victory at sea. A consequence of the quality of training given them is their superior state of readiness. Its result is a victorious Navy.

This taining manual (TRAMAN), NAVEDTRA 10662, and nonresident training course (NRTC), NAVEDTRA 80662, will enable Utilitiesmen second class to help themselves fulfill the requirements of their rating. Among these requirements are the abilities to plan, schedule, supervise, and perform tasks involved in the installation, maintenance, and repair of plumbing, heating, steam, compressed-air, air-conditioning, and refrigeration systems, and water treatment and distribution systems.

Designed for individual study and not formal classroom instruction, the TRAMAN provides subject matter that relates directly to the occupational standards of the Utilitiesman rating. The NRTC provides a way of satisfying the requirements for completing the TRAMAN. The assignments in the NRTC include learning objectives and supporting items designed to lead the student through the TRAMAN.

This TRAMAN was prepared by the Naval Education and Training Program Management Support Activity, Pensacola, Florida for the Chief of Naval Education and Training. Technical assistance was provided by the Naval Facilities Engineering Command, Alexandria, Virginia; the Naval Construction Training Center and the Civil Engineering Support Office, Port Hueneme, California; and the Naval Construction Training Center, Gulfport, Mississippi.

1990 Edition

Stock Ordering No.
0502-LP-212-7200

Published by
NAVAL EDUCATION AND TRAINING
PROGRAM MANAGEMENT SUPPORT ACTIVITY

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON, D.C.: 1990

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CONTENTS

CREDITS

The illustrations listed below are included in this edition of Utilitiesman 2 through the courtesy of the designated sources. Permission to use these illustrations is gratefully acknowledged. Permission to reproduce illustrations and other materials in this publication must be obtained from the source.

Source	Figures
Allis-Chalmers Industrial Pumps	4-4, 4-5, 4-6, Tables 4-1, 4-2
Ford Motor Company	14-29, 14-31, 14-34
Frick Company	14-4
Lennox Industries Corporation	9-25, 14-1, 14-2, 14-3, Tables 9-1, 9-2
National Association of Plumbing-Heating-Cooling Contractors	3-17, 3-18
Pellerin-Milnor Corporation	12-2, 12-3, 12-5
Scott Aviation	6-9
Trane Company	13-4, 14-8, 14-19, 14-20, Table 14-2
Vilter Manufacturing Corporation	Table 13-1
Wallace & Tiernan Division Pennwalt Corporation	5-1, 5-2, 5-3, 5-4, 6-3

REGULATIONS ON ENVIRONMENTAL POLLUTION AND HAZARDOUS MATERIALS

Environmental Pollution and Hazardous Waste Handling and Disposal programs have been enacted and are United States law. These programs are of immense importance and should be taken into consideration during the planning stages before beginning any new construction or rehabilitation project.

As a member of the Naval Construction Forces, United States law requires you to be constantly aware of potential environmental pollution hazards or hazardous material spills and to report them to your immediate supervisor or other senior personnel at the earliest possible time.

The following list of directives contains information on the cognizant government departments and the procedures for preventing, reporting, and correcting environmental pollution hazards and hazardous materials disposal worldwide:

- Naval Occupational Safety and Health Program Manual, OPNAVINST 5100.23B
- Environmental and Natural Resources Protection Manual, OPNAVINST 5090.1
- Domestic Wastewater Control, MIL-HDBK 1005/8

CHAPTER 1

ADMINISTRATIVE DUTIES AND SAFETY RESPONSIBILITIES

Learning Objective: Recognize characteristics and administrative duties of a crew leader, and identify the elements of a safety organization.

This training manual has been prepared to help you, as members of the Navy and Naval Reserve, increase your knowledge of the Utilitiesman rating and to advance in rating. You should review the *Utilitiesman 3* training manual before starting this training manual. This manual picks up subject matter in the *Utilitiesman 3* and goes into greater detail to prepare you for second class petty officer by covering the occupational standards.

You still have a lot to learn about utilities work, such as the installation, operation, maintenance, and repair of equipment. You may be called on from time to time to fill the role of a supervisor. At first, your supervisory duties and responsibilities are limited, but they increase as you advance from one paygrade to the next. This chapter discusses three areas that are important: administration, safety, and tools. Although it does not tell you all you need to know, you should get an idea of what to expect in the way of administrative duties, safety, and tool responsibilities.

ASSIGNMENT AS CREW LEADER

As you gain experience in utilities work, you will probably be called upon to serve as the leader of one or more crews. They may perform various types of work, such as measure, cut, and thread pipe; install pipe lagging and other insulation and protective materials on pipe; or clean watersides and firesides of boilers. Your duties as a crew leader may vary from one activity to another. Usually, they involve planning work assignments, supervising work teams, preparing requisitions, and keeping time cards.

PLANNING WORK ASSIGNMENTS

Planning is the process of determining requirements and devising and developing methods and schemes of action for construction of a project. Proper planning saves time and money for the Navy and makes the project easier for everyone concerned. Here are some pointers that are designed to help you plan day-to-day work assignments for your crew(s).

When you are assigned a job, whether in writing or orally, one of the first things to do is to make sure you understand clearly just what is to be done. Study plans and specifications where applicable. If you have any questions, find out the answers from those in a position to supply the information you need. Among other things, make sure you understand the priority of the project, time of completion, and any special instructions to be followed.

In planning for a small or a large project, you must consider the capability of the personnel available for assignment. Determine who is to do what and how long it should take to complete the job. Realizing that idleness may breed discontent, arrange to have another job ready for starting as soon as the first one is finished.

Establish goals for each workday and encourage your crew to work together as a team in accomplishing these goals. You want goals to be such that your crew is kept busy, but make sure they are **realistic**. During an emergency, most people will make a tremendous effort to meet a deadline. But people are not machines, and when there is no emergency, they cannot be expected to continually achieve an excessively high rate of production. In planning, you must also allow for things that are not considered direct labor, such as safety training, disaster control training, leave, and liberty.

To help ensure that a job is done properly and on time, you should consider the method to use in doing the job. If there is more than one way, make sure the method you select is the best. After selecting a method, analyze it to see

if it could be simplified and still save time and effort.

Plan material requirements so you will not have a lot of leftover materials. But do not make material estimates so low that you might run out of necessary items and cause the job to be delayed, and your crew to stand around idle until new supplies can be obtained. At times, you may have to use more materials then anticipated, so it is better to have some leftover materials than to run short.

Consider the tools and equipment you need for the job and arrange to have them available at the place where the work is to be done, and at the time the work is to get under way. Determine who is to use the tools, and make sure these individuals to whom they are assigned know how to use them properly and safely. Determine whether special permits are required to operate special tools. Plan to have the materials in an accessible place that will not pose a safety hazard.

SUPERVISING WORK TEAMS

After the job has been properly planned, it is necessary to supervise the job carefully to ensure it is completed properly and on time. Some pointers for supervising work teams are given below.

Before starting a job, make sure your crew members know what is to be done. Give instructions clearly, and urge them to ask questions on any points that are unclear. If they do not understand the requirements, they will be unable to do their job properly. It is also important to ensure the crew members know all pertinent safety precautions and wear safety apparel as required. Check all tools and equipment before use to ensure they are in a safe condition. Ensure electrical tools are marked with the current safety color code. The color code for any given month will be uniform for a 30-day period or less, according to COMCBPAC/COMCBLANTINST 5100.1. Ensure all electrical power tools are protected by GROUND FAULT INTERRUPTER (GFI) before use. Do not permit dangerously defective tools and equipment to be used; see that they are turned in for repair immediately. A job can be done without a specific tool by substitution, but people are not as expendable.

While the job is under way, check from time to time to ensure the work is progressing satisfactorily. Determine if the proper methods, materials, tools, and equipment are being used. If one of your crew members is doing a job wrong, stop and point out what is wrong. Then, explain the correct procedure and check to see that it is done. In checking the work of your crew, make sure they know that the purpose of your inspection is to teach, guide, and direct, rather than to criticize and find fault. Ask questions to show interest, and praise good, sound ideas and judgment.

When time permits, rotate the crew members on various jobs. Rotation gives them varied experience and helps to ensure that you will have a person who can do the work if someone is hospitalized, transferred, or goes on leave.

A good supervisor should be able to get others to work together in getting the job accomplished. The supervisor should maintain an approachable attitude toward the crew, making members feel free to come and seek advice when they are in doubt as to any phase of the project. Emotional balance is especially important; a supervisor cannot become panicky in front of the crew. A good supervisor should use tact and courtesy in dealing with members of the crew and not show partiality to certain members. The supervisor should keep crew members informed on matters that affect them personally or concern their work. The supervisor should also seek to maintain a high level of morale, keeping in mind that low morale can have a definite effect upon the quantity and quality of work being turned out by the crew.

The information above is only a brief treatment on the subject of supervision. As you advance in rate, you will be spending more and more of your time supervising others, so make a continuing effort to learn more about the subject of supervision. Study books on supervision, as well as leadership. Also, read articles on topics of concern to supervisors such as safety, training, job planning, and so forth, that appear from time to time in trade journals and other publications. There is a big need in the Navy for petty officers who are skilled supervisors. Consider the role of supervisor as a big challenge and endeavor to become proficient in all areas of the supervisor's job.

SAFETY DUTIES OF SUPERVISORY PERSONNEL

Safety is a matter of chief concern to every supervisor. The supervisor who continuously has an outstanding safety record for the shop or fieldwork team has a lot to be proud of. Safety precautions relating to specific operations performed by the Utilitiesman are presented in various portions of this training manual. In this discussion, we are concerned with the safety

organization of a Naval Mobile Construction Battalion (NMCB), the safety training responsibilities of a crew petty officer, and the reporting procedures that a crew petty officer must carry out if a subordinate has a mishap (accident). Although these responsibilities may seem somewhat distant now, the sooner you start thinking about them, the better prepared you will be when it comes time to assume them. As a Utilitiesman third class studying for advancement to Utilitiesman second class, you can reasonably expect to assume these duties in the near future.

BATTALION SAFETY ORGANIZATION

As a supervisor in an NMCB, you should know the safety organization structure of the battalion. This is important since you cannot function as a crew petty officer in an intelligent and informed manner unless you are aware of how you fit into the battalion's scheme of safety. In other words, you should know who (or what group) in the battalion decides and establishes the safety policies and procedures you must follow. You should also know who will be your source of safety guidance in training and supervising your crew. In addition, you should know to whom your mishap (accident) reports are routed, and more importantly, why this information is sought.

Every NMCB is required by COMCBLANT/COMCBPAC instruction to provide a formal safety organization (fig. 1-1). The three principal

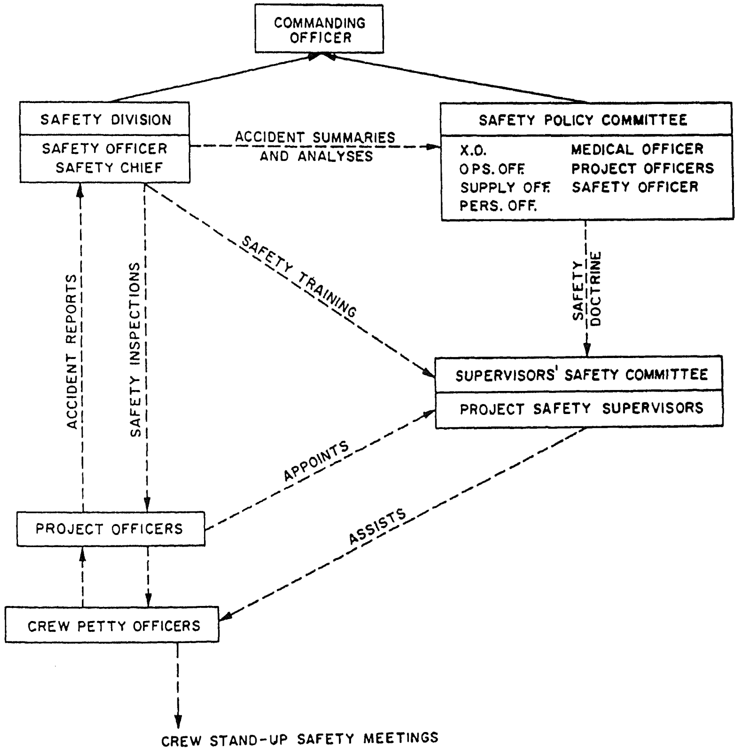


Figure 1-1.—NMCB safety organization.

agencies of this organization are the Safety Policy Committee, the Safety Division, and the Supervisors' Safety Committee.

Safety Policy Committee

The SAFETY POLICY COMMITTEE is headed by the executive officer and includes among its members the operations officer, supply officer, personnel officer, medical officer, safety officer, and any other members the commanding officer may wish to appoint. As its name suggests, the primary purpose of the committee is to formulate safety doctrine and policy for the battalion. To do this, the committee must continually review and evaluate the work practices of the battalion, particularly mishaps (accidents), to be able to recommend practical and effective safety precautions.

Safety Division

The SAFETY DIVISION is detailed to ensure that the procedures established through the Safety Policy Committee are carried out properly and promptly throughout the battalion. The Safety Division is normally composed of the safety officer, the safety inspector, and whatever number of additional assistants as may be necessary. The position of safety officer is assigned by the commanding officer and is under the direct supervision and control of the commanding officer.

Perhaps the first responsibility of the Safety Division is to constantly survey and inspect the battalion for unsafe practices and conditions. It is this area that the safety officer uses to best advantage. It is also his responsibility to visit and inspect every jobsite, shop, camp, and galley throughout the battalion. The safety officer's job is, however, much more than just being a safety monitor. He also acts as an advisor and consultant during these inspections, meets informally with supervisors to answer questions, and helps develop and encourage safe practices. The safety officer has the authority and obligation to stop any operations or practice that might cause injury to personnel or damage to material or equipment.

The safety division, under the safety officer, is also responsible for receiving and reviewing all mishap (accident) reports and for preparing summaries and analyses of these reports. The safety officer also reviews the supervisor's proposals for corrective action and recommends acceptance of these proposals, when appropriate.

Another important function of the Safety Division is to provide a safety training program throughout the battalion. It might be stressed that the Safety Division (safety officer) is your primary source of safety information and guidance. This information and guidance should be passed to you through your project safety supervisor, whom we will discuss in a moment. The safety officer, frequently with the assistance of the educational services officer (ESO), provides for safety lectures, instructions, demonstrations, and many other activities centered on safety, such as safety movies, safety awards ceremonies, and placement of safety posters. As part of this safety training program, the safety officer is also responsible for organizing and coordinating the crew level safety briefings, called stand-up safety meetings, which are conducted by the crew supervisor or crew petty officer. More information on stand-up safety meetings is presented later.

Supervisors' Safety Committee

A third safety group established in every NMCB, and the one with which you, as a petty officer and supervisor, will perhaps have the most direct contact, is the SUPERVISORS' SAFETY COMMITTEE. This committee is composed of all the project safety supervisors in the battalion. Before the deployment of an NMCB, the construction expected of the battalion is identified and organized into units of work called projects. Each project is given a number and assigned a project officer (often a chief petty officer), who has overall responsibility for the safe and successful completion of the project. To assist in maintaining the necessary safety programs in the project, the project officer selects a capable petty officer, first or second class, and assigns that person the collateral duty of project safety supervisor. The duties of the project safety supervisor are rather considerable. If you should become a crew petty officer, the project safety supervisor is your primary contact in practically all matters concerning safety. For the moment, however, we are interested in the project safety supervisor as a member of the Supervisors' Safety Committee.

The purpose of this last committee is to act as a focal point for the exchange of safety information and policies between the various projects. Since crews from different projects often work close together, the hazards peculiar to the work of one crew sometimes affect the other and vice versa. The Supervisors' Safety Committee thus provides a convenient assembly where one project can apprise the others of its work procedures and related safety precautions. The committee also forms a convenient avenue by which any crew, or any individual, can forward recommendations for improved safety methods to the Safety Policy Committee.

The Safety Division, the Safety Policy Committee, and the Supervisors' Safety Committee, together, make up the formal safety organization of an NMCB; that is, those groups whose duties and functions center solely on safety. As a petty officer, however, and particularly as a crew petty officer supervising a job, you will be preoccupied with many other responsibilities other than safety. Nevertheless, the fact remains that the ultimate achievement of safety in an NMCB rests with you. In truth, the Safety Division, the Safety Policy Committee, and the Supervisors' Safety Committee all operate to support you as a supervisor.

SAFETY DUTIES OF A PETTY OFFICER

Petty officers are responsible for the safety of personnel placed in their charge. They must be alert and focus their attention on all unsafe working conditions. Basically, your safety duties revolve around training your subordinates, correcting unsafe practices and conditions should they occur, and being prepared to execute certain procedures should one of your crew be involved in a mishap (accident).

Safety Training

New methods and procedures used in performing construction operations and working in new and different situations, all require the supervisor to keep everyone informed of the latest in construction safety. Besides, you can never assume that people transferred to your crew from some other crew are appropriately and fully trained in safety matters. For these reasons, the safety education and training of subordinates is a continuing responsibility of every supervisor.

To keep the crew informed, every crew petty officer periodically holds short (approximately 5 to 15 minutes) safety meetings, called stand-up safety meetings. During this meeting, the crew petty officer briefs the crew on hazards and precautions relating to current work. Although the crew petty officer is responsible for the actual conduct of the meetings, much of the content of the briefing is organized and assembled by the Safety Division and passed to the crew petty officer through the project safety supervisor.

In addition to the stand-up safety meetings, the crew petty officer is, of course, also concerned with the minor day-to-day instruction and training of the crew on the job. It is beyond the scope of this text to go into a discussion of teaching or training methods. (See chapter 6, *Military Requirements for Petty Officer Third Class*, NAVEDTRA 10044.) However, a few words on the petty officer's approach to safety and safety training at the crew level might be appropriate. The job of achieving safety in your crew is, like most other supervisory functions, essentially a matter of leadership. In studying and seeking to understand the practical aspects of directing and managing a crew, many new petty officers fail to recognize the power of personal example in leading and teaching subordinates. You will soon discover, in this regard, that subordinates are very quick to detect any difference between what you say and what you do. You cannot reasonably expect your crew to measure up to standards of safety conduct and awareness that you yourself do not constantly DEMONSTRATE. It is not enough to be knowledgeable in the various aspects of construction safety. As a supervisor, you must make your genuine concern for the importance of crew safety visible to your crew members at all times. Leadership by example may not be the only technique of leadership, but it is one of the most practical and time-proven methods of management available to you.

Mishap Reporting Procedures

A well-planned and conscientiously executed crew safety program will prevent mishaps. Nevertheless, you must be prepared to carry out certain procedures should a person in your charge be injured or otherwise involved in a mishap. For mishap (accident) reporting, OPNAVINST 5102.1 series, *Mishap Investigation and Reporting*, defines a mishap as "Any unplanned or unexpected event causing personal injury, occupational illness, death, material loss or damage, or

an explosion of any kind whether damage occurs or not." This OPNAVINST also defines an injury as "Traumatic bodily harm, such as a cut, fracture, burn, or poisoning, caused by a single or one day exposure to an external force, toxic substance, or physical agent." If an injury is the type that requires first aid or medical attention and the man can be returned to duty within 24 hours, or can resume some light form of work within 24 hours, the formal investigation and reporting procedures ordinarily are not necessary. This is not to say, however, that you need not investigate these kinds of mishaps (accidents) on your own. Small or seemingly harmless incidents often repeat themselves with more serious results. If an improper practice or condition exists in your crew, you must obviously identify and correct it before a serious mishap (accident) occurs.

Suppose that one of your crew members is injured; the first priority, of course, is to arrange for prompt medical treatment. At the same time, you must also take steps to prevent additional injuries or damage by shutting off power, stopping equipment or machinery, posting guards, and so on. Next, see to it that the project officer is notified of the mishap. If the mishap occurs outside working hours, then the officer of the day should be notified. If the mishap causes any physical impairment that will prevent a person from performing regularly established duty for a period of 24 hours or more subsequent to 2400 of the day of injury, then it may be your responsibility as crew petty officer to investigate the circumstances and submit a written report. OPNAVINST 5102.1 series gives the requirements for this report.

This reporting requirement is in effect at all times. However, if one of your crew members is injured during nonworking hours, the safety officer is responsible for conducting the investigation and submitting the report. The elements of a mishap report of personal injury are in chapters 2 and 3 of OPNAVINST 5102.1 series. If you have any questions as to when this report is required, routing instructions, and so on, consult your project safety supervisor.

Public Works Department Safety Organization

The Public Works Department Safety Organization (fig. 1-2) is very similar to the

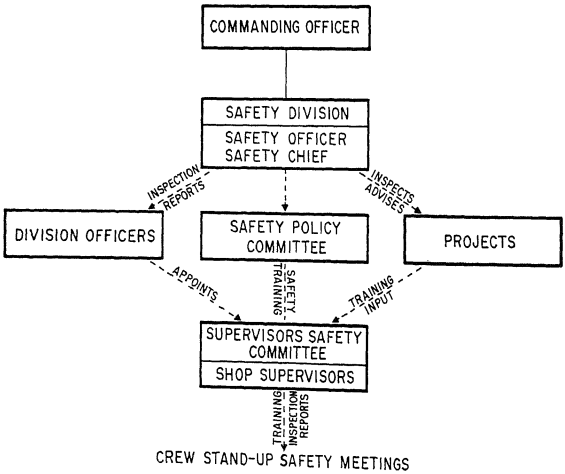


Figure 1-2.—Public works department safety organization.

Battalion Safety Organization, except on a smaller scale. The safety officer on some small activities is the security officer, or sometimes a civilian worker is tasked with this assignment. The safety chief is usually a public works chief with this task being assigned as collateral duty. The safety petty officers are usually shop supervisors. Meetings are conducted much as they are in a battalion and safety lectures are given by the shop supervisors in the same manner.

REFERENCES

Mishap Investigation and Reporting, OPNAVINST 5102.1A, Office of the Chief of Naval Operations, Washington, D.C., 1982.

CHAPTER 2

PLANS, SPECIFICATIONS, AND COLOR CODING

Learning Objective: Identify blueprint notes, specifications, and common symbols used with mechanical drawings, and recognize classes of materials, their color codes, and markings.

Drawing or sketching is the universal language used by engineers, technicians, and skilled craftsmen. Whether this drawing is made freehand or with drawing instruments, it is needed to convey necessary information to an individual who will fabricate and assemble the object whether it is a building, ship, aircraft, or mechanical device. When several people are involved in the fabrication of an object, copies (prints) are made of the original drawing or tracing so everyone involved has the same information. Not only are drawings used as plans to fabricate and assemble objects, they are also used to illustrate the manner in which machines, ships, aircraft, and so on, are operated, repaired, and maintained.

This chapter contains general information concerning blueprints. After studying this chapter, you should be able to tell what information is contained on a blueprint, and where this information is located. In addition, you should be able to draw simple freehand sketches and to specify the hazards associated with each color used to code pipes and compressed gas containers.

BLUEPRINTS

Blueprints are reproduced copies of mechanical or other types of technical drawings. The term *blueprint reading* means interpreting the ideas expressed by others on drawings, whether the drawings are actually blueprints or not. Various types of blueprints (usually referred to as plans) are used in the construction, operation, and maintenance of buildings and equipment. The most common types of blueprints are defined below.

"Preliminary Plans" are plans submitted with bids, or other plans submitted before the award of a contract.

"Contract Plans" are plans that show design features of a building that are mandatory requirements.

"Contract Guidance Plans" are plans that show design features of a building that are subject to development.

"Standard Plans" are plans that show the arrangement or details of equipment, systems, or components for which specific requirements are mandatory.

"Type Plans" are plans that indicate the general arrangement of equipment, systems, or components. These plans do not require strict compliance to the details, provided the required results are accomplished.

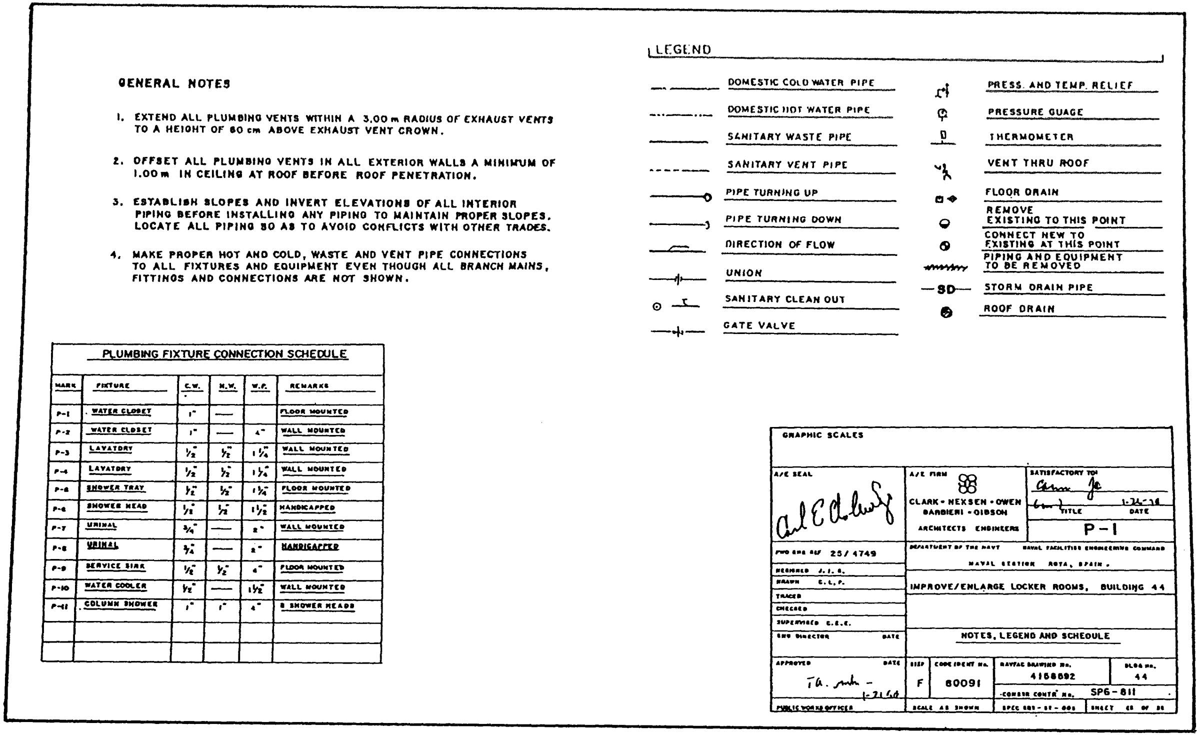
"Working Plans" are contractor construction plans that are necessary for contraction of the building.

"Corrected Plans" are working plans that have been corrected to show the final building and system arrangement, fabrication, and installation.

"Onboard Plans" are a designated group of plans that show the features considered necessary for the rehabilitation of a building.

NOTES AND SPECIFICATIONS

Blueprints contain all the information about an object or part that can be presented graphically (that is, in a drawing). A considerable amount of



MARK	FIXTURE	C.W.	H.W.	W.F.	REMARKS
P-1	WATER CLOSET	1"	—		FLOOR MOUNTED
P-2	WATER CLOSET	1"	—	4"	WALL MOUNTED
P-3	LAVATORY	1/2"	1/2"	1 1/4"	WALL MOUNTED
P-4	LAVATORY	1/2"	1/2"	1 1/4"	WALL MOUNTED
P-5	SHOWER TRAY	1/2"	1/2"	1 1/4"	FLOOR MOUNTED
P-6	SHOWER HEAD	1/2"	1/2"	1 1/2"	HANDICAPPED
P-7	URINAL	3/4"	—	2"	WALL MOUNTED
P-8	URINAL	3/4"	—	2"	HANDICAPPED
P-9	SERVICE SINK	1/2"	1/2"	4"	FLOOR MOUNTED
P-10	WATER COOLER	1/2"	—	1 1/2"	WALL MOUNTED
P-11	COLUMN SHOWER	1"	1"	4"	8 SHOWER HEADS

54.582

Figure 2-1.—A plumbing plan.

information can be presented this way, but there is more information required by supervisors, contractors, manufacturers, and craftsmen that cannot be presented in a graphic format. Information of this type is generally given on the drawings as notes or as a set of specifications attached to the drawings.

NOTES are generally placed on a drawing to provide clarifying information about the object on the blueprint. Leader lines are used to indicate the precise part being annotated. Figure 2-1 shows the need for a typical plumbing plan.

A SPECIFICATION is a statement or document containing a description or enumeration of such particulars as the terms of a contract or the details of an object or objects not shown on a blueprint or drawing. Specifications (specs) describe the items in enough detail so they may be procured, assembled, and maintained according to the performance requirements; furnish sufficient information to determine whether conformance to each specification has been realized; and furnish the above information in sufficient detail so the job can be accomplished without additional research, development, design engineering, or assistance from the preparing organization. Federal specifications cover the characteristics of material and supplies used jointly by the Navy and other government departments. All federal specifications used by the Navy Department as purchase specifications are listed in the *Department of Defense Index of Specifications and Standards.*

LEGEND OR SYMBOLS

When it is used, the LEGEND is generally located in the upper right-hand corner of a blueprint just below the revision block. The legend is used to explain or define special symbols and marks on a blueprint. Figure 2-1 shows a legend for a plumbing plan. As a rule, the plumbing plans show the location of the fixtures and fittings to be installed and the size and the route of the piping. The basic details are left to the plumber (UT) who is responsible for installing a properly connected system according to the specifications and good plumbing and construction practices.

Generally, plumbing plans consist of four types of symbols: piping, fittings, valves, and fixtures. Symbols used on piping prints listed in MIL-STD-17B, Part 1, are shown in figure 2-2. Note that the symbols may indicate types of connections (screwed, flanges, welded, and so forth), as well as various fittings, valves, gauges, and items of equipment. When a symbol is needed for an item not covered in the standards, a suitable symbol must be designed by the activity concerned. When a new symbol is used, it is normally explained by a note on the drawing. Figure 2-3 shows some of the common pipeline symbols used in conjunction with piping prints. When a print shows more then one piping system of the same type, additional letters are added to the symbols to differentiate between the systems.

FREEHAND SKETCHING

There may be times when subordinates and fellow workers do not understand a part of a plan to be used in their work. To help explain the work, you may want to make a freehand sketch of the part that is confusing to them. The freehand sketch is a rough outline of the confusing part of the plan and usually contains the angles, dimensions, and details required to make the sketch clear to the user. Sketches also can partially perform the duties of remote supervision by providing all the information that you, as a supervisor, would provide if you were present. This permits you to attend to other important duties. Additionally, you may want to explain a new idea to your supervisor and find that a visual presentation in the form of a freehand sketch will help sell the idea.

For all of these reasons, plus the requirement of the occupational standards, you must be able to make freehand sketches.

The Utilitiesman who can make quick, accurate sketches has another way of conveying technical information and ideas. Almost every drawing or graphic problem begins with a sketch. The sketch is part of thinking and sharing. It is a means of talking effectively with experts. So, learn to sketch your ideas. Look for opportunities to sketch. If you wonder about your first attempts, sit down by yourself and be your own audience. Do not worry about being perfect right now. Do think about communicating. Why the sketch in the first place? Do you need it? Be your own critic. Your sketch is one way of reaching out with your ideas.

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

D 207.208/2:UT3/3

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

D 207.208/2:U 75/5

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

D 207.208/2:U 3/5

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document
must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

D 207.208/2:UT 3/3

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual (TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

Naval Education and
Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

S/N 0502-LP-212-7200

Naval Education and Training Command

NAVEDTRA 10662
April 1990
0502-LP-212-7200

Training Manual
(TRAMAN)

Utilitiesman 2

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Nonfederal government personnel wanting a copy of this document must use the purchasing instructions on the inside cover.

S/N 0502-LP-212-7200

it. The photographs in figure 8-31 will give you an idea of how devices may be used in locking out valves.

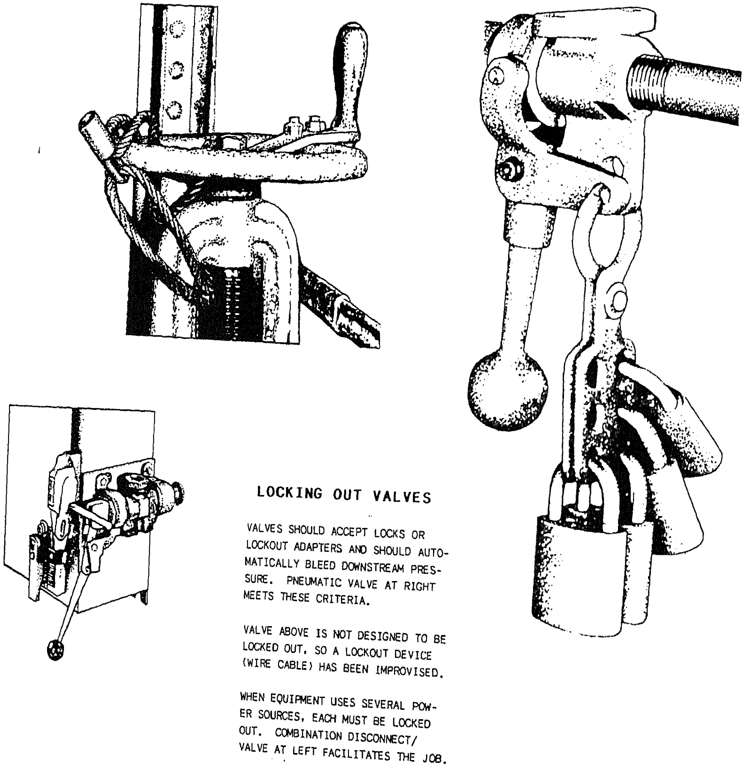
Multiple Lock Adapter

It is often an advantage for a lockout device to accommodate more than one padlock. In this way, when you are working on a machine or an item of equipment with the valve locked off, another person can come along and use the padlock to do other hazardous work on the machine or equipment at the same time—rather than wait until you are finished.

Since most controls are not designed to accommodate more than one padlock at a time, multiple lock adapters called lockout clamps or tongs may be used. (See fig. 8-32.) These adapters should be permanently chained to the control, or, alternately, issued to all people with padlocks.

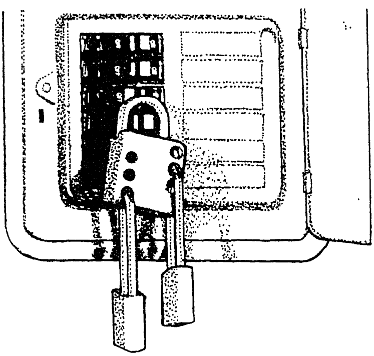
Locks

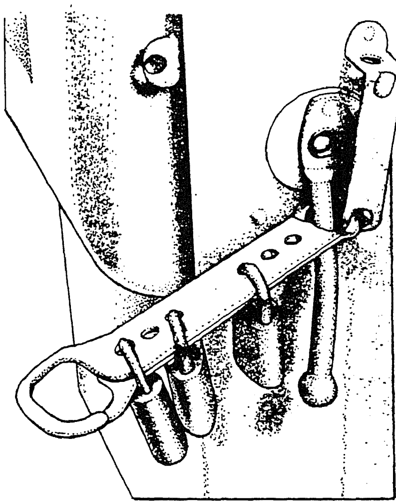
Perhaps you are wondering what kind of lock should be used, key or combination? What person should have a lock? Who should be in possession of the keys or combinations? How

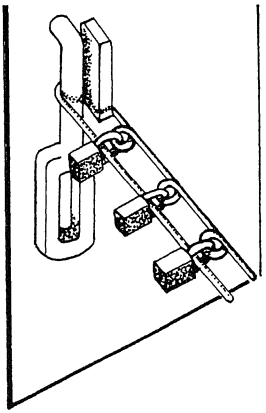


54.283

Figure 8-31.—Locking out valves.







MULTIPLE LOCK ADAPTERS

MULTIPLE LOCK ADAPTERS ALLOW SEVERAL PADLOCKS TO BE USED ON THE SAME SWITCH LEVER OR VALVE HANDLE. THEY ARE VARIOUSLY CALLED "LOCKOUT CLAMPS," "LOCKOUT TONGS," AND "LOCKOUT SCISSORS." THE PHOTO AT RIGHT SHOWS TYPICAL TONG-TYPE ADAPTER ON SWITCHBOX LEVER.

AT UPPER LEFT, A HASP-TYPE ADAPTER ACCOMMODATES TWO LOCKS THAT GUARANTEE FLIP-SWITCH WILL REMAIN "OFF" UNTIL LAST MAN HAS FINISHED HIS WORK.

DIAGRAM AT LOWER LEFT ILLUSTRATES A SHOP-MADE MULTIPLE LOCK ADAPTER FORMED OF 3/16-INCH STEEL WIRE. COULD BE DESIGNED TO TAKE ANY NUMBER OF LOCKS.

54.284

Figure 8-32.—Multiple lock adapters.

should the lock be identified? The answers to these questions may vary from one activity to another, but some guidelines are presented.

1. Key-operated padlocks are more commonly used than combination locks. Supervisors can control keys easier than combinations.

2. Locks should be issued to every person who works on closed-down equipment. No key (or combination) should fit more than one lock.

3. Only one key should be issued to a person authorized to use the lock. At some activities, the supervisor may be permitted to maintain a duplicate set of keys for locks under his/her control, or a master key. Some activities, however, may have only one lock—one key. In an emergency, bolt cutters may be used to remove a lock. As a word of caution: KEYS AND LOCKS SHOULD NEVER BE LOANED.

4. Locks should identify the user by name, rate, and shop. This information can be stamped into the lock case, stenciled on, or carried on a metal tag fixed to the shackle of the lock. In addition, locks may be color coded to identify the skill or rating of the lock holder, such as UT, CE, or CM. The colors could also follow the hard hat color code.

Lockout Procedure

If locks, lockout devices, and multiple lock adapters are to be effective, they must be used properly on every occasion where they are needed. Make sure that you follow the steps of the lockout procedure below.

1. Before any equipment is locked out, there should be agreement as to the specific machine or unit to be taken out of operation. The supervisor should oversee lockout procedures.
2. Turn off the point-of-operation controls. (Remember that disconnect switches should never be pulled while under load, because of the possibility of arcing or even explosion.)
3. See that the main power controls (switch, breaker, or valve) are turned OFF. Where electrical voltages are involved, do NOT attempt this yourself but have it done by a Construction Electrician.
4. After the switch has been opened or the valve closed, the person who will be doing the work should snap the locks on the control lever or multiple lock adapter. At this point, tag the switch, valve, or device being locked. Tags should indicate the type of work being done, approximately how long the job will take, and the name of the supervisor.
5. Try the disconnect or valve to make sure it cannot be moved to ON.
6. Try the machine controls as a test to ensure the main controls are really off.
7. As each person completes work, only that person should remove the lock and supplemental tag. The person removing the last lock should notify the supervisor that the work is finished and the equipment is ready to be placed back in operation.

REFERENCE

Cleaver-Brooks Operation, Service, and Parts Manual, Nos. 750-90 and 750-91, Cleaver-Brooks Division of Aqua-Chem Inc., Milwaukee, Wisc., 1983.

CHAPTER 9

WARM-AIR HEATING

Learning Objective: Identify the procedures for installing, operating, maintaining, and troubleshooting warm-air heating systems.

Advances in the field of warm-air heating have made it one of the most popular and widespread forms of heating in use today. It has the advantage of adaptability with various fuels and can be used in a variety of buildings, including barracks, hangars, personnel housing, schools, and theaters. It is likely, therefore, that at one time or another you will be responsible for performing technical maintenance and for the repair and installation of warm-air heating equipment.

This chapter contains material on installing, maintaining, repairing, and troubleshooting of warm-air heating systems and the operation and control of warm-air heating equipment.

WARM-AIR HEATING EQUIPMENT

Heating equipment for complete air-conditioning systems is classified according to the type of fuel burned, the Btu capacity of the furnace, and the method of circulating the warm air. Two types of warm-air furnaces are the gravity system and the forced-air circulating system.

GRAVITY SYSTEM

Gravity furnaces are often installed at floor level. These are really oversized jacketed space heaters. The most common difficulty experienced with this type of furnace is a return-air opening of insufficient size at the floor. Make the return-air opening on two or three sides of the furnace wherever possible. Provide heat insulation above the furnace top to avoid a possible fire hazard.

Gravity warm-air heating systems operate because of the difference in specific gravity (weight) of warm air and cold air. Warm air is lighter than cold air and rises when cold air is available to replace it.

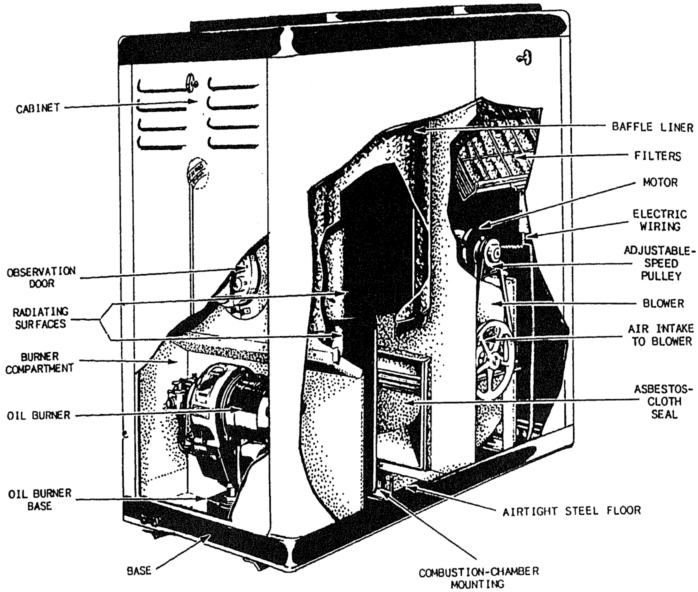
FORCED-AIR SYSTEM

The majority of the furnaces produced today are of the forced warm-air type. This type of furnace includes the elements of a gravity warm-air system plus a fan to ensure adequate air distribution. It may include filters and a humidifier to add moisture to the air. The inclusion of a positive pressure fan makes possible the use of smaller ducts and the extension of the system to heat larger areas without the need for sloping ducts. It is possible to heat rooms located on floors below the furnace if necessary. Forced-air furnaces are manufactured in a variety of designs. A typical oil-fired furnace is shown in figures 9-1 and 9-2. A typical gas-fired furnace is shown in figure 9-3.

In a forced-air system, the fan or blower is turned on and off by a blower control which is actuated by the air temperature in the bonnet or plenum. The plenum is that part of the furnace where it joins the main trunk duct. (See fig. 9-4.) The blower control starts the fan or blower when the temperature of the heated air rises to a set value and turns the fan or blower off when the temperature drops to a predetermined point. Thus, the blower only circulates air of the proper temperature.

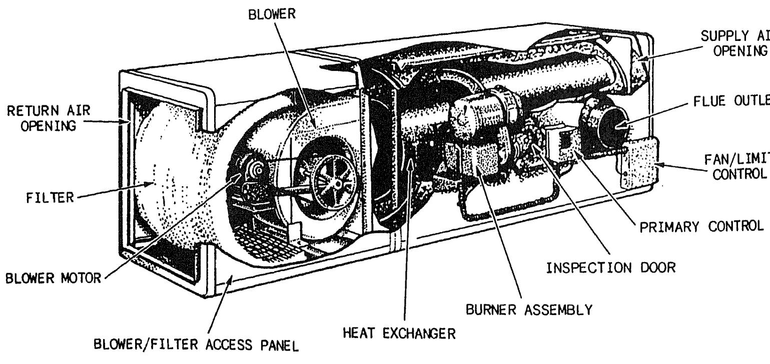
AIR DISTRIBUTION

A knowledge of air distribution principles is important when dealing with central warm-air heating systems. Satisfactory heating from warm-air systems is absolutely dependent upon proper distribution of warm air from the heat source to all portions of the space served. Warm air must be distributed in quantities that are required to offset the rate of heat released to each room. With



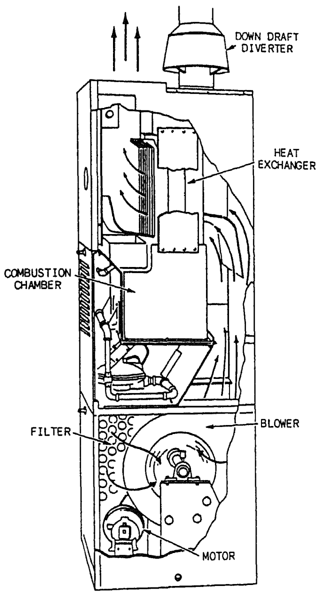
87.72

Figure 9-1.—Cutaway view of a typical oil-designed furnace.



54.591

Figure 9-2.—Cutaway view of a horizontal stowaway oil furnace.



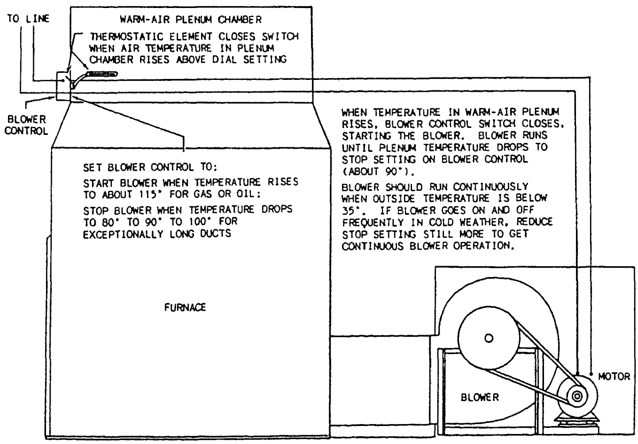
54.373

Figure 9-3.—Gas-fired vertical warm-air furnace.

radiator systems, distribution is primarily a problem of getting enough hot water or steam to each radiator to be sure the radiator heats to its rated capacity. It is not possible to deliver more heat through steam or hot water than the radiator is designed to transmit. With warm-air systems, however, the amount of heat reaching each room is determined by the rate of air delivery and the temperature of the air delivered to the room. Temperature balance, then, is mostly a problem of controlling air distribution.

Factors, such as velocity, volume, temperature, and airflow direction, play an important part in temperature balance. In addition, and for human comfort, space-temperature variations and noise levels must also be considered. Convection currents result from the natural tendency of warm air to rise and cold air to fall, the temperature variations near doors and windows, and from the more dense cool air that is drawn away quicker than warm air. Objectionable noise will result at supply diffusers if room velocities exceed 25 to 35 feet per minute (fpm). Air stratification and cold floors may also result when supply diffusers are not properly located within the space.

Patterns of air distribution vary with the positions of supply diffusers. A diffuser that discharges through the floor in an upward direction or downward through the ceiling



87.74

Figure 9-4.—Electrical circuit showing how blower control operates blower motor when temperature in plenum rises.

provides a vertical distribution of air. On the other hand, a diffuser that discharges through a wall provides a horizontal distribution of air. The spread for either the horizontal or the vertical pattern depends on the setting of the diffuser vanes. A low horizontal discharge provides the most effective distribution. Air distribution that results from different diffuser locations is shown in figure 9-5.

Warm-air heating systems are generally identified as either the GRAVITY TYPE or the FORCED-AIR TYPE. These installations are further identified by the type of duct distribution used. There are two types of duct layouts: (1) the INDIVIDUAL DUCT, where each duct is connected directly to the furnace plenum, and (2) the TRUNK AND BRANCH DUCT, where the trunk duct connects to the furnace plenum and then branches off to the outlets. These two types are shown in figures 9-6 and 9-7.

Gravity-type furnaces are rated in leader area capacity, the LEADERS being the warm-air pipes. With respect to return ducts, the register-free area and the return-air duct should not be less than 1 1/4 times the area of the leader serving a given area. Gravity-type installations, as shown in figure 9-7, use the individual duct layout.

Forced warm-air systems usually have a register temperature range of 150 °F to 180 °F. Ducts can be in the form of a trunk with branches or with individual leaders from a plenum chamber. Furnaces used with forced-air installations must be equipped with automatic firing devices. Velocities usually are in the range of 750 to 900 fpm in trunks, and approximately 600 fpm in branches. Outlet velocities at registers may be as high as 350 fpm.

GAS-FIRED FURNACES

In this section, construction features, basic components, gas burners and controls of gas-fired furnaces are discussed.

CONSTRUCTION FEATURES

The various gas-fired furnaces available today have similar basic components; however, there are variations in design with respect only to

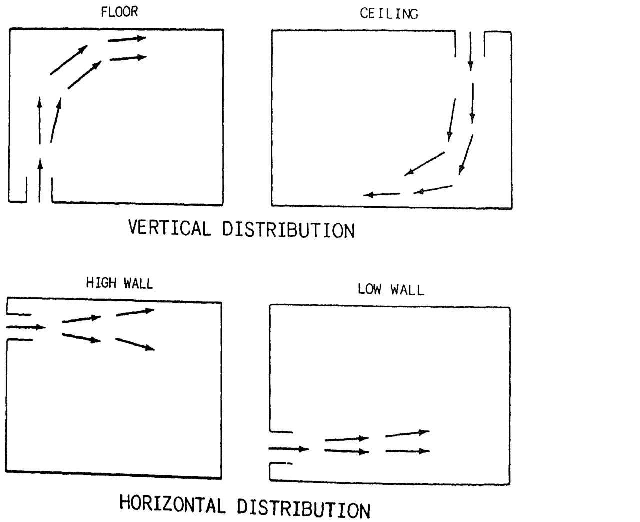
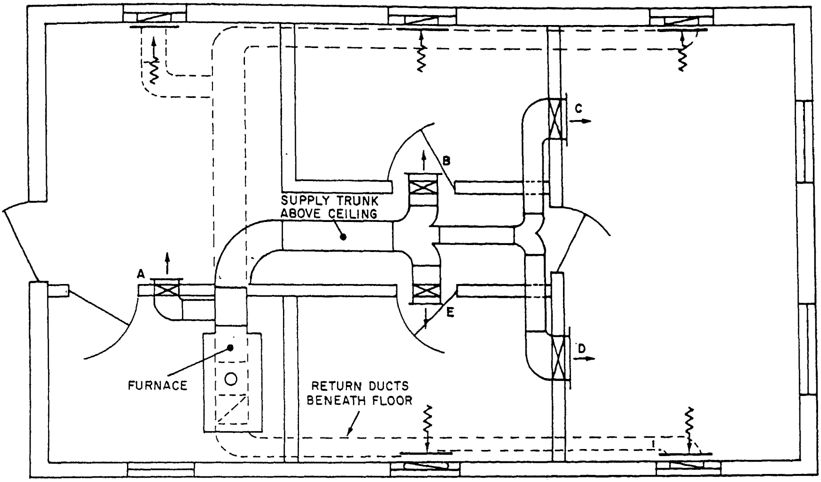
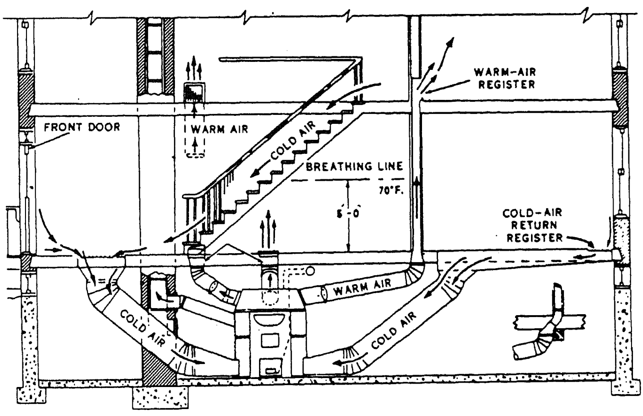


Figure 9-5.—Air diffuser distribution.



87.276

Figure 9-6.—Trunk and branch duct distribution systems.



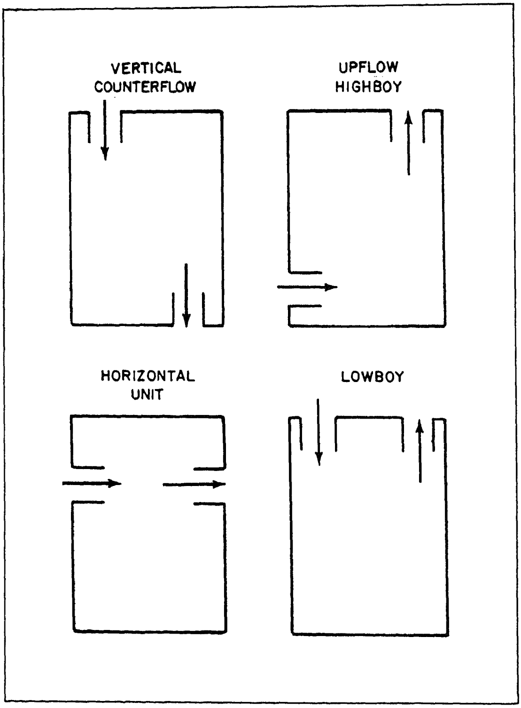
87.274

Figure 9-7.—A typical gravity warm-air heating system (individual duct).

dimensions and airflow. Unit features pertinent to dimensions and airflow are important when selecting a furnace for a particular space or application. A vertical counterflow unit, for example, is normally used where supply ducts are located beneath the floor because it has the return in the top and the outlet in the bottom. The most commonly used unit is the UPFLOW HIGHBOY which, as a rule, draws air from the side or bottom and discharges it from the top. It can be installed in small spaces. In the HORIZONTAL UNIT, the air flows in one side and out the other. This unit is suitable for installation in crawl spaces, attics, and basements. In another type, sometimes called a LOWBOY, both the return and the outlet are at the top. It is a shorter and wider version of the upflow unit. The different airflows are shown in figure 9-8.

Another type of furnace is the DUCT FURNACE. It is designed for mounting in a duct system where air circulation is provided by an external fan. It is generally used with an air-conditioning system to supply heat during the heating season by using the same ductwork. This type can be installed as a single unit or in batteries for larger requirements. A typical gas-fired duct furnace is shown in figure 9-9.

Gas-fired furnaces have three main parts: the return-air compartment that houses the blower and filter components; the warm-air compartment



87.277

Figure 9-8.—Furnace airflow designs.

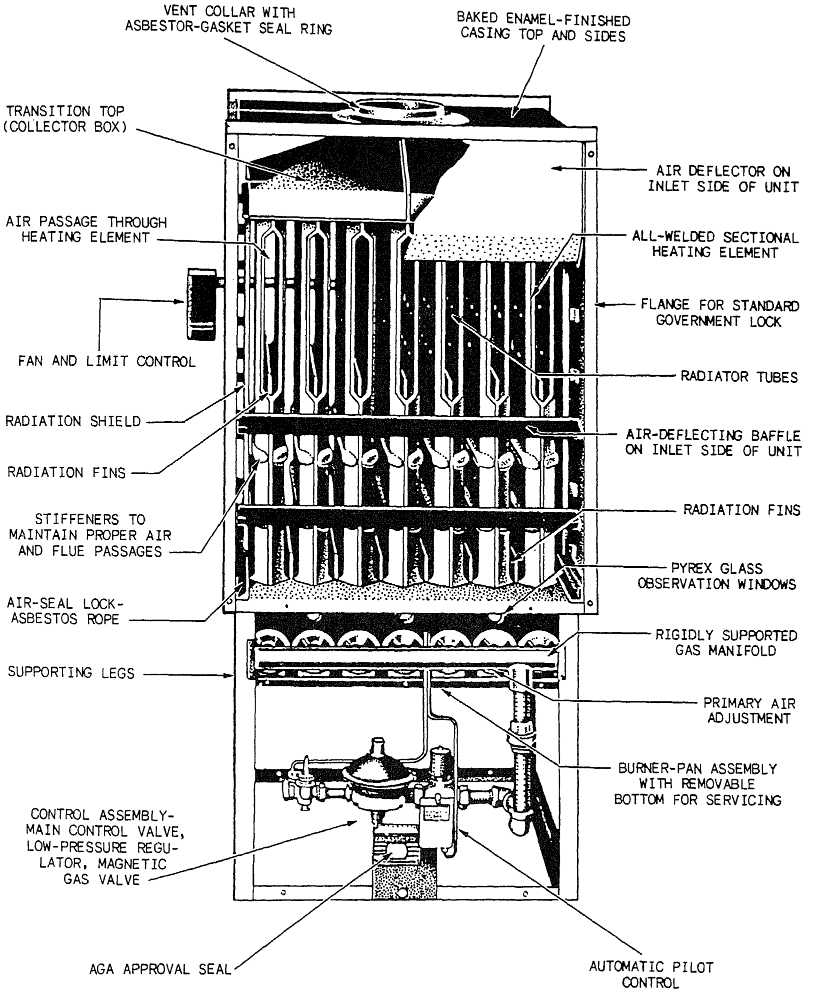


Figure 9-9.—Typical gas-fired duct furnace.

that includes the heat exchanger radiators and combustion enclosure; and the combustion air and fuel compartment. This arrangement is shown in figure 9-10.

BASIC COMPONENTS

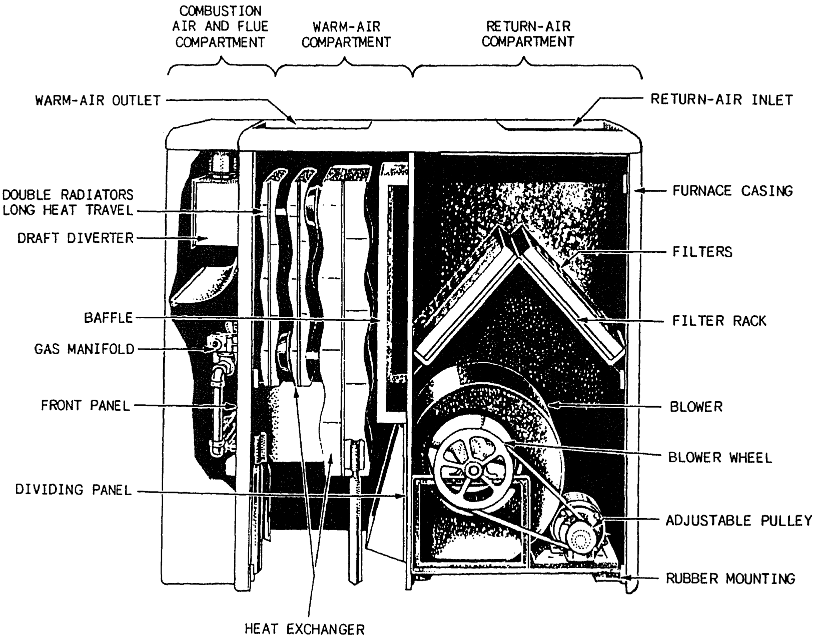
The components and assemblies of a gas-fired furnace can be broken down into six units. Each unit is discussed briefly below. Refer to figures 9-9 and 9-10 as we go along to identify the location of individual parts.

The furnace casing, sometimes called the cabinet, along with the framework, contains and supports the components of the unit. It also provides an insulating chamber for directing return air through the heat exchanger into the warm-air outlet.

The blower is a centrifugal fan that provides the circulation required to move warm air across the heated space. It also pulls the return air from the space back to the furnace.

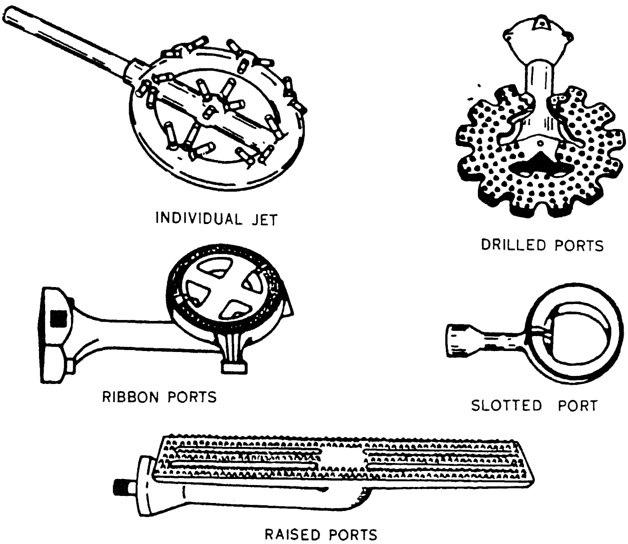
The burners are usually the Bunsen type regardless of their size or shape. Figures 9-11 and 9-12 show Bunsen burners. The flame is nourished by the burner as it provides the correct mixture of primary air and fuel gas to the combustion area.

The gas manifold assembly includes the gas valves, pressure regulator, and those components that automatically control the flow of gas to the



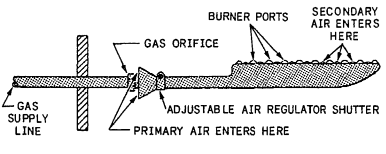
87.75

Figure 9-10.—Internal view of furnace.



87.279

Figure 9-11.—Typical Bunsen burners.



54.377

Figure 9-12.—Bunsen type of burner.

pilot and main burner. It is directly connected to the burner.

GAS BURNERS AND CONTROLS

To use natural gas, a nearly ideal fuel, requires comparatively simple equipment and unskilled labor. This gas is almost free of noncombustibles and is therefore clean. However, it is relatively dangerous compared to coal or oil because it mixes easily with air and burns readily. Extreme care must be exercised to prevent or stop any leakage of gas into an unlighted furnace or into the boiler room. All gas burners should be approved by the American Gas Association and installed according to the standards of the National Board of Fire Underwriters.

The gas burners used in gas-fired furnaces usually have a nonluminous flame and are the Bunsen type, as shown in figures 9-11 and 9-12. Part of the air needed for combustion is primary air that is drawn into the burner mixing tube or venturi, where it mixes with the gas that burns at the burner's ports. The secondary air is supplied around the base of each separate burner flame by natural draft or is induced by a draft fan.

The gas burner controls include the following units: manual gas valve, gas pressure regulator, solenoid gas valve, diaphragm valve, pilot light, thermocouple, thermocouple control relay, limit control, heat exchanger, draft diverter, and

humidifier. (See fig. 9-13.) A manual gas cock or valve must be installed ahead of all the controls.

Manual Gas Valve

The manual gas valve is installed on the heating unit next to the gas pressure regulator. It is used to shut off the gas to the heating unit in case some of the controls must be repaired or replaced.

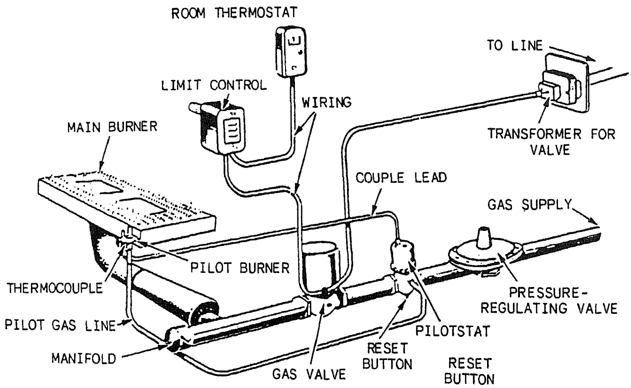
Gas Pressure Regulator

The gas pressure regulators used in domestic gas-heating systems are usually of the diaphragm type, like those shown in figures 9-13 and 9-14. A gas pressure regulator maintains the desired pressure in the burner as long as the gas main pressure is above the desired pressure. When the gas pressure to the burner is low, the pressure-regulating spring pushes the diaphragm down, in turn, pushing the pilot valve down. When the pilot valve opens, supply pressure is applied to the top of the operating piston. As the operating piston moves down, the main valve opens, admitting supply pressure to the burner. As burner pressure rises, the diaphragm is pushed up against the pressure-regulating spring, closing the pilot valve. This removes the supply pressure from the top of the operating piston and the piston return spring pushes the piston up, closing the main valve. The regulator is thus closed every time the burner pressure gets above the desired amount. The setting of the regulator can be varied by turning the adjusting screw at the top of it.

Solenoid Gas Valve

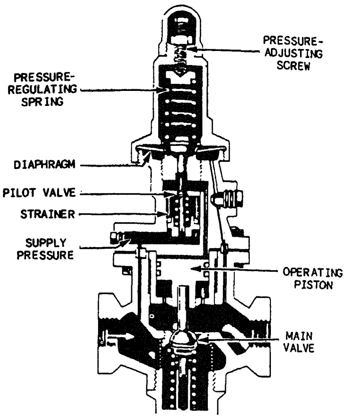
The basic principles of construction and operation applied in all solenoid gas valves are similar. However, the design of each individual unit differs somewhat from the others. The two most common types of solenoid gas valves are the standard solenoid valve and the recycling solenoid valve discussed in the following paragraphs.

The standard solenoid gas valve shown in figure 9-15 is of the electric type. It is suitable for use with gas furnaces, steam and hot-water boilers, conversion burners, and industrial furnaces. This valve operates when a thermostat, limit control, or other device closes a circuit to energize the coil. The energized coil operates a plunger, causing the valve to open. When there is a current failure, the valve automatically closes because of the force of gravity on the plunger and valve stem. The gas pressure in the line holds the valve disk upon its seat. To open this valve during current failure, use the manual opening device at the bottom of the valve. When the electric power is resumed, you should place the manual opening device in its former position.



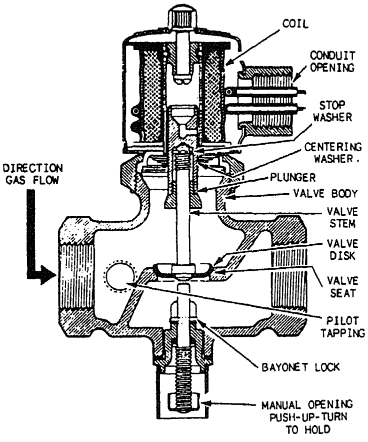
54.378

Figure 9-13.—An automatic gas burner control system.



54.379

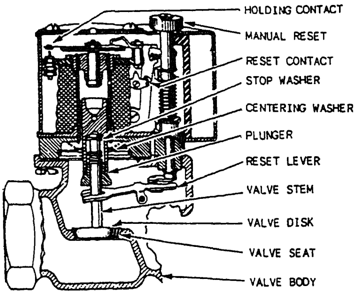
Figure 9-14.—A gas pressure regulator.



54.380

Figure 9-15.—A standard gas solenoid valve.

The recycling solenoid gas valve shown in figure 9-16 can be used with the same heating equipment as the standard solenoid gas valve. The design of this valve differs from that of the standard solenoid gas valve because it is equipped



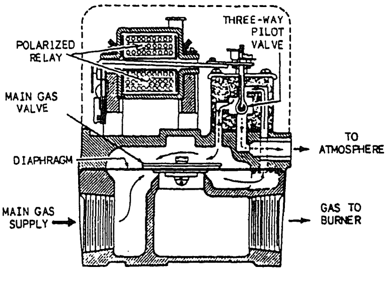
54.381

Figure 9-16.—A recycling solenoid valve.

with an automatic recycling device that allows the valve to switch to manual operation during power failure. However, upon the resumption of power, the thermostat automatically resumes control of this valve.

Diaphragm Valve

The diaphragm gas valve shown in figure 9-17 can be used interchangeably with a solenoid gas valve. Its main feature is the absence of valve noise when it is opening or closing. In this type of diaphragm valve, the relay energizes and opens the three-way valve so the gas pressure on the top of the diaphragm is released to the atmosphere. Reducing the pressure on the top of the diaphragm in this manner causes the gas supply pressure to



54.382

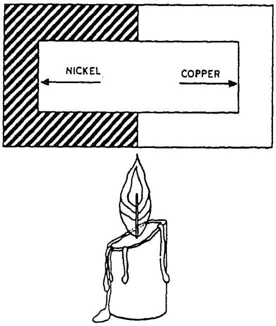
Figure 9-17.—A diaphragm gas valve.

flex the diaphragm upward, opening the main gas valve. When the relay is de-energized, the vent to the atmosphere is sealed and pressure from the gas supply is allowed to be applied to the top of the diaphragm, forcing it down and sealing the main valve.

Pilot Light

The gas pilot light in a gas-heating unit is a small flame that burns continuously and lights the main burner during normal operation of the heating unit. It is located near the main burner, as shown in figure 9-13.

The gas flow to the pilot light is, in some cases, supplied by a small, manually operated gas shutoff valve on the main gas line above the main gas valve. In other cases, the gas can be supplied from the pilot tapping on a solenoid gas valve, as shown in figure 9-15. In more expensive heating units, the gas for the pilot light is often supplied by a thermocouple-controlled relay.



54.383
Figure 9-18.—The principle of a thermocouple.

Thermocouple

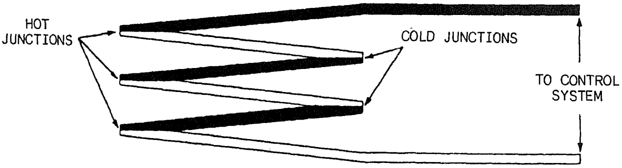
A thermocouple is probably the simplest unit in the electrical field which is used to produce electric current by means of heat. It is constructed of two U-shaped conductors of unlike metals in the form of a circuit, as shown in figure 9-18. Suppose that these conductors were composed of copper and nickel, respectively, and joined as shown in the figure; then two junctions between the metals would exist. If one of these junctions were heated by a flame, a weak electric current would be produced in the circuit of these conductors. A series of junctions can be arranged to form a thermopile to increase the amount of current produced, as shown in figure 9-19.

In the heating field, thermocouples and thermopiles are used to produce the electrical current used to operate such units as gas valves, relays, and other safety devices.

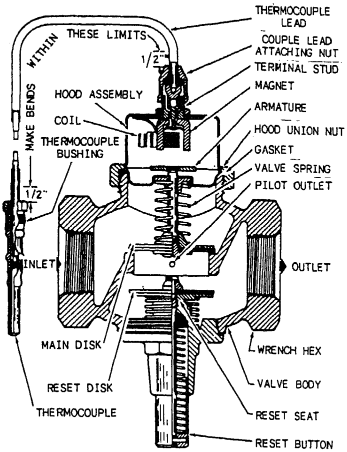
The thermocouple is located next to the pilot light of the main gas burner, as shown in figure 9-13. It generates the electric current (usually 50,000 microvolts) which holds open a main gas valve, a relay, or any other safety devices, permitting gas to flow to the main burner. Soon after the pilot light is extinguished, current ceases to flow to these safety devices, thus causing them to shut off the gas to the heating unit. These safety devices will not operate again until the pilot light is lighted and current is again generated by the thermocouple.

Thermocouple Control Relay

The thermocouple-operated relay shown in figure 9-20 is a safety device used on gas-fired heating equipment. The thermocouple, when placed in the gas pilot flame, generates electricity. The electric current energizes an electromagnet that holds a switch or valve in the open position as long as the pilot flame is burning. When the



54.384
Figure 9-19.—A thermopile.



54.385

Figure 9-20.—A typical thermocouple and valve relay assembly.

pilot flame goes out because of high drafts or fuel failure, the electromagnet is de-energized, thus closing and preventing the opening of the switch or valve. The closing of the valve or switch prevents the burner from filling the combustion chamber with unburned gases.

To relight the pilot light, push up the reset button at the bottom of the relay and allow the gas to flow to the pilot light. Since some heating units are not equipped with relays, the pilot light is not automatically shut off in case of gas supply failure.

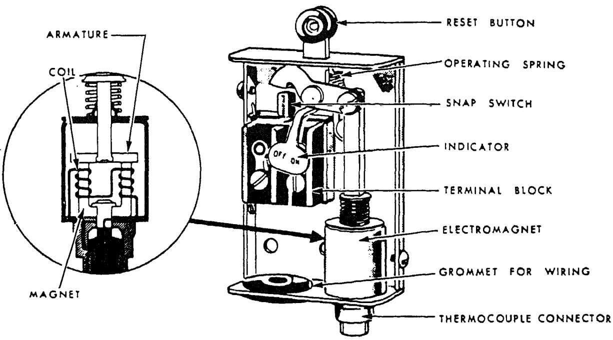
The relay shown in figure 9-21 is an electrical switch type of relay. It is entirely electrical and can be used as a controlling unit for either the magnetic or diaphragm gas valves. This unit is also actuated by the electric current generated by the thermocouple, and it controls the operation of the gas valve in the magnetic and diaphragm valves. A relay of this type must also be reset manually for normal operation.

Limit Control

The limit control in a gas burner system is a safety device. It shuts off the gas supply when the temperature inside the heating unit becomes excessive. The limit control device can be adjusted to the desired setting. It exercises direct control on the gas or diaphragm valve.

Heat Exchanger

This unit or assembly may be either a single or sectional contoured steel shell. It extends vertically from the burner enclosure to the flue exit. Functionally, it transmits heat from the hot gases of combustion to the circulating warm air that passes the outer surfaces.



54.386

Figure 9-21.—An electric switch type of relay.

Draft Diverter

The diverter is simply a sheet metal chamber that encircles the flue. It has an opening at the bottom to allow air to be drawn in by the flue draft. Its purpose is to reduce the downdrafts and updrafts that are objectionable to pilot and burner operation.

Humidifiers

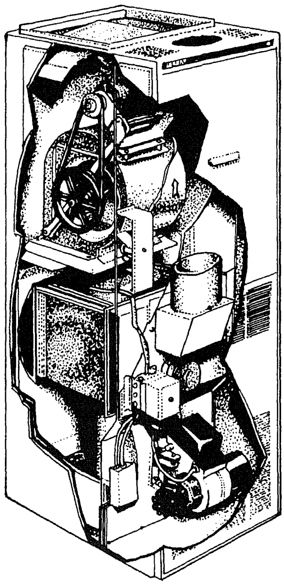
Humidifiers used with forced warm-air heating systems are usually of the pan type shown in figure 9-22. Unless the water is relatively free of solids, these humidifiers require frequent attention, since the float may stick in the open position or the valve may clog. Overflowing of the pan may result in a cracked heating section, and a stopped-up inlet valve will make the humidifier inoperative.

The drum type of evaporative humidifier uses an evaporation pad in the shape of a wheel. The slow-turning wheel is submerged in the water in the lower pan where the spongelike plastic foam material becomes saturated with water. The wheel lifts this portion of the pad and exposes it to the warm dry air flowing through it. The air then absorbs more moisture because of lower relative humidity at the higher temperatures.

OIL-FIRED FURNACES

Oil-fired furnaces are similar to gas-fired units in physical arrangement. Internally, oil-fired units have three areas: the burner compartment, the combustion and radiating chamber, and the blower compartment. Figure 9-23 shows a cutaway view of a typical oil-fired furnace.

Like gas-fired units, oil-fired units are also available with various airflow designs. The model shown in figure 9-1 is designed with both the return-air inlet and the warm-air outlet in the top.

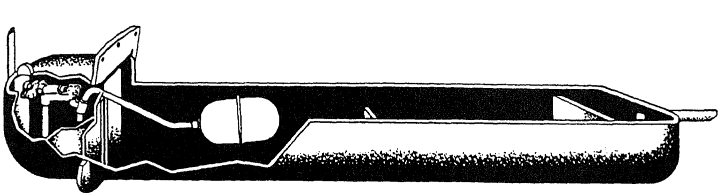


87.72.1

Figure 9-23.—Cutaway view of a typical oil-fired furnace.

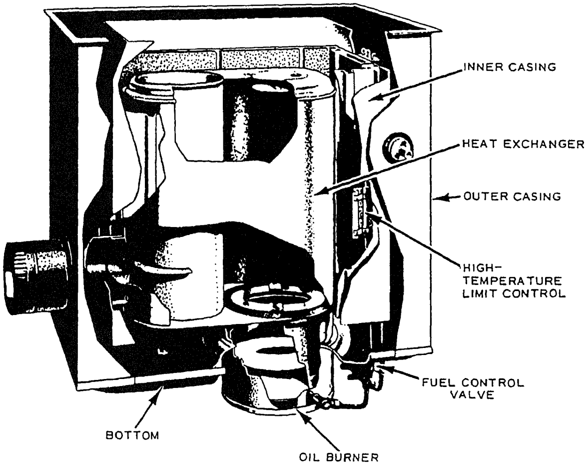
More compact models (fig. 9-23) are available with the return-air inlet at the side or bottom below the radiating and combustion area. The warm-air outlet is at the top.

A floor furnace is shown in figure 9-24. This type of oil-fired unit is smaller and lighter in construction and is designed to be hung from the floor of the space served. Only a minimum of clearance is required below the floor.



87.79

Figure 9-22.—Cutaway view of a typical humidifier.



87.287

Figure 9-24.—Oil-fired floor furnace.

Oil burners may be separated into various classes, such as domestic and industrial. Since domestic oil burners are used almost universally in warm-air furnaces, they are the only ones covered in detail in this chapter.

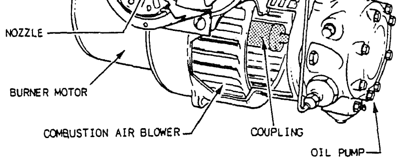
DOMESTIC OIL BURNERS

Domestic oil burners are usually electrically power driven and are used in small central heating plants.

Domestic oil burners atomize the oil. They also deliver a predetermined quantity of oil and air to the combustion chamber, ignite it, and automatically maintain the desired temperature. Domestic oil burners are classified according to various methods, none of which is entirely satisfactory because of the overlapping among a great number of models. Classification may be by type of ignition, draft, operation, method of oil preparation, or features of design and construction.

Design and Construction

One of the most common types of domestic oil burners is the pressure-atomizing gun type of burner. Gun type of burners atomize the oil by fuel oil pressure. The fuel oil system of a pressure-atomizing burner consists of a strainer, pump, pressure-regulating valve, shutoff valve, and atomizing nozzle. (See fig. 9-25.) The nozzle and



54.375.1X

Figure 9-25.—High-pressure gun type of oil burner.

electrode assembly includes the oil pipe, nozzle holder, nozzle, strainer, electrode insulators, electrodes, supporting clamp for all parts, and static disk. The oil pipe is a steel rod with a fine hole drilled through it. This reduces oil storage in the nozzle to a minimum to prevent squirting at the nozzle when the burner shuts off.

The air system consists of a power-driven blower with means to throttle the air inlet, an air tube that surrounds the nozzle and electrode assembly, and vanes or other means to provide turbulence for proper mixing of the air and oil. The blower and oil pump are generally connected by a flexible coupling connected to the burner motor. Atomizing nozzles can be furnished to suit both the angle of spray and the oil rate of a particular installation. Flame shape can also be varied by changing the design of the air exit at the end of the air tubes; oil pressures are usually about 100 psi, but pressures considerably greater are sometimes used.

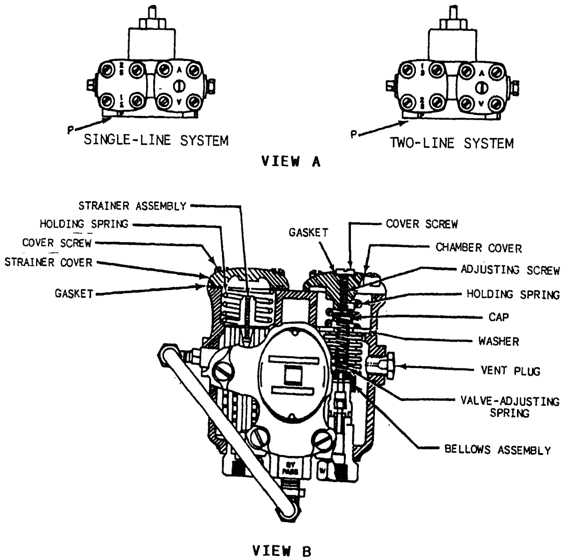
Electric ignition is almost exclusively used. Electrodes are located near the nozzle but must not be in the path of the fuel oil spray. The step-up transformer provides the high voltage (usually 10,000 volts) necessary to make an intense spark jump across the electrode tips.

Fuel Unit

There are many types of fuel units available for oil burners; however, the T-type, two-stage fuel unit is the most commonly used. Figure 9-26 shows this type unit. It is an oil pump with two strainers mounted on the body of the oil burner and operated by the blower motor shaft.

The T-type, two-stage fuel unit can be used on a single-line or on a two-line system. When the Number 1 on the strainer cover is next to the letter *P* marked on the body of the pump, it is correctly arranged for a single-line system. It is set up for a two-line system when the cover is turned so the Number 2 is adjacent to the same letter *P*.

A two-line system is necessary when the bottom of the fuel tank is below the level of the



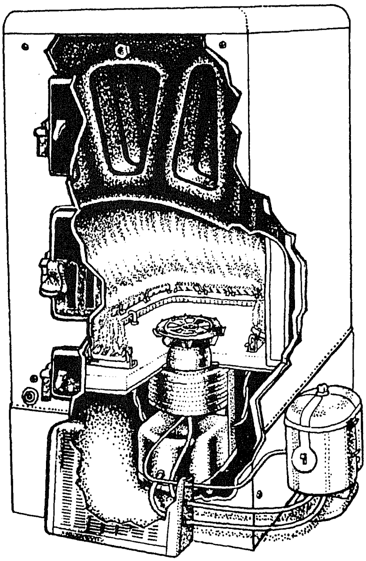
87.291

Figure 9-26.—A typical T-type, two-stage fuel pump.

pump. The suction line from the tank is connected to the pump port marked "Inlet." The return line is connected to the pump bypass port and is directed back into the tank. With the one-line system, the return line is not used.

IGNITION ELECTRODES.—The fuel is ignited by the heat of a spark jumping between two ignition electrodes. (See fig. 9-25.) The voltage necessary to cause the spark to jump is much more than the line voltage available. Therefore, an electric transformer is used to step up the line voltage to approximately 10,000 volts.

The wall flame burner has an oil distributor and fan blades mounted on a vertical shaft directly connected to the motor. The oil distributor projects the oil to a flame ring made of either refractory material or metal. Figure 9-27 shows this type of burner. The hot flame ring vaporizes the oil, and the oil vapors mix with air and burn with a quiet blue flame that sweeps the walls of the furnace. Ignition may be electric, gas-electric, or gas. High-grade fuel oil is necessary for satisfactory performance.

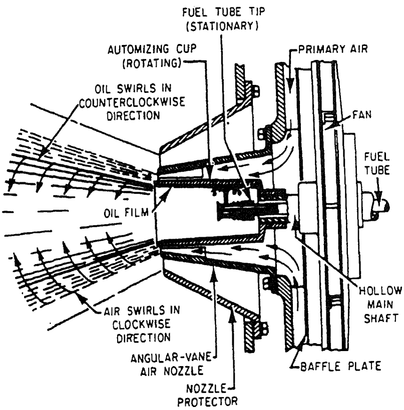


87.289

Figure 9-27.—Vertical rotary burner of the vaporizing or wall flame type.

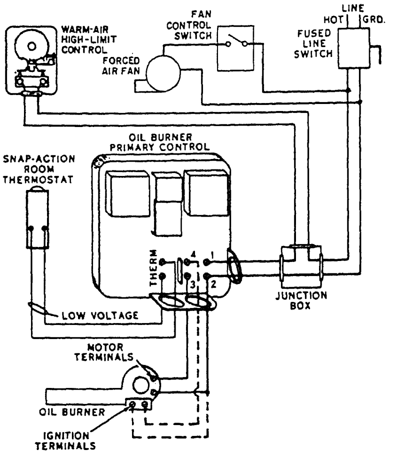
HORIZONTAL ROTARY TYPE.—This type was originally designed for industrial use; however, sizes are available for domestic use. It has a wider range of fuel-burning capacity than the high-pressure gun type and can accommodate heavier grades of fuel. Figure 9-28 shows this type of burner.

The major parts of the burner are the housing, fan, motor, fuel tube, and rotating atomizing cup. The atomizing cup and fan are driven at the same speed by a directly connected electric motor. Oil is fed through the fuel tube to the inner surface of the atomizing cup. The oil spreads over the surface of the cup, which turns at 3,450 revolutions per minute (rpm). It then flows to the edge of the cup where it is thrown off. The whirling motion and the resulting centrifugal force separates the oil into fine particles as it leaves the cup. Primary air supplied by the fan is thrown in around the outer edge of the rotating cup and given a whirling motion in the direction opposite that of the oil. The streams of air and oil collide and thoroughly mix as they enter the combustion chamber.



87.290

Figure 9-28.—A horizontal-rotary oil burner.



54.374

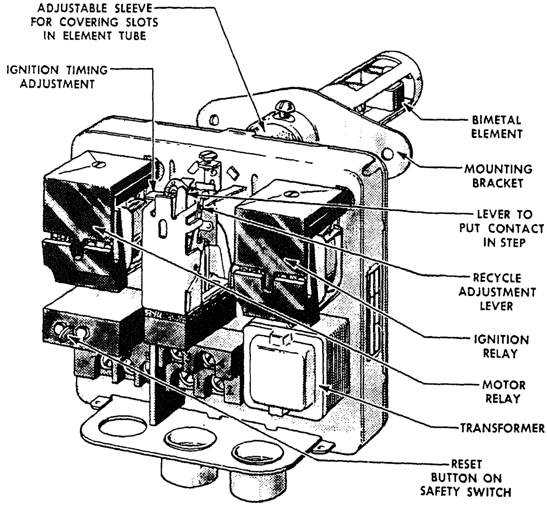
Figure 9-29.—Typical forced warm-air control system.

Oil-Burner Controls

The purpose of oil-burner controls is to provide automatic, safe, and convenient operation of the oil burner. The system is designed to maintain the desired room temperature, to start the burner as required, and to ignite the fuel to initiate combustion. However, in case trouble arises during operation, the burner must be stopped and further operation prevented until the trouble has been corrected.

Oil-burner controls are essentially the same as stoker or gas controls. The only difference is that the oil burner has, in addition, two ignition electrodes and a primary or safety control. A diagram of a typical forced warm-air control system is shown in figure 9-29.

PRIMARY CONTROL.—The burner primary control is electrically connected between the thermostat and the burner, as shown in figure 9-29, and it performs several functions. The primary control closes the motor and ignition



87.84

Figure 9-30.—Interior view of a primary control.

circuits when the thermostat calls for more heat. It breaks the motor circuit and stops the burner when the motor first starts if the fuel fails to ignite or if the flame goes out. The control prevents starting of the burner in case of electrical failure until all safety devices are in the normal starting position.

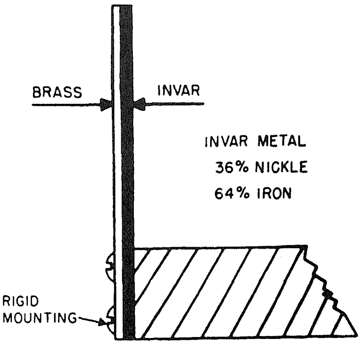
An interior view of a primary control is shown in figure 9-30. This control device is also equipped with a high-temperature limit control. This control shuts down the heating plant whenever the temperature of the furnace becomes excessive. For example, if the thermostat is exposed to a blast of cold air for a long period of time, the heating plant could run long enough to become overheated to the point of severe damage or external fire if it was not for this high-temperature limit control.

LIMIT CONTROL.—The limit control is a device that responds to changes in air temperature (in a warm-air heating system), to changes in water temperature (in a hot-water heating system), and to changes in steam pressure (in a steam-heating system). The limit control has two distinct functions. The first function is to control the operation of the fire so the temperature and pressure of the heating plant never exceeds safe operating limits. This function is distinctly for safety control.

The second function of the limit control is to limit the temperature and pressure of the heating system for better temperature regulation in the building. This function is particularly useful in controlling coal-fired heating systems where the coal bed continues to give off heat when the stoker motor stops. By lowering the setting of the limit control, however, it is possible to prevent an excessively hot fire that would continue to throw off excessive amounts of heat after the thermostat has been satisfied.

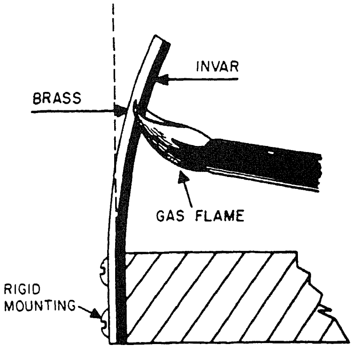
TEMPERATURE-RESPONSIVE DEVICES.—Many automatic control units, such as the thermostat, limit control, fan control, and many others, must respond to temperature changes. Actually, these are the instruments that use a temperature change to cause the electrical contacts inside each unit to open and close. The opening and closing is an indicating signal that is transmitted to the primary control for specific action, such as starting or stopping the operation of the heating plant.

BIMETALLIC STRIP.—Some automatic control units are equipped with a switch that contains a straight bimetallic strip to open and close electrical contacts. This actuating device is made by welding together two pieces of dissimilar metals, such as brass and Invar, as shown in figure 9-31. Below a certain predetermined temperature, this strip does not deflect or bend. However, when the strip is heated, it bends in the direction of the metal that expands the least, as shown in figure 9-32.



54.523

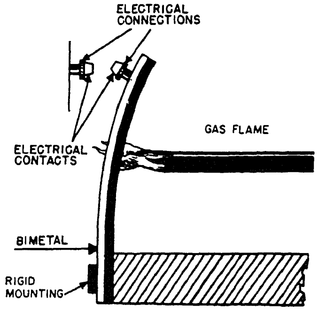
Figure 9-31.—Bimetallic strip.



54.523.1

Figure 9-32.—Expanded bimetallic strips.

Actually, this electrical switch is constructed, as shown in figure 9-33, by welding two electrical connections and contacts to the strip. A switch of this type can then be used to control electrical circuits because the bimetallic strip responds to temperature changes. This is a basic example of how this principle of bimetallic strip operation is used in many temperature-responsive automatic units. Other control switches contain bimetallic strips that are spiral, U-shaped, Q-shaped, or even in the shape of a helix, as shown in figure 9-34.

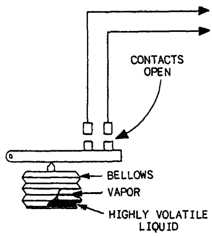


54.523.2

Figure 9-33.—Electrical switch.

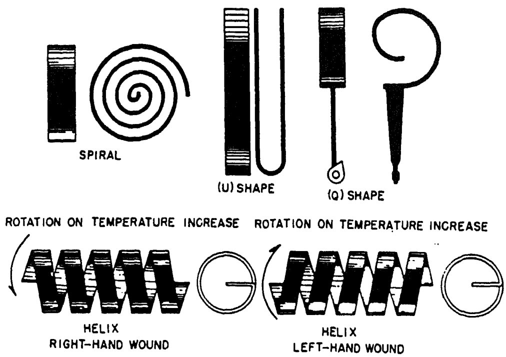
VAPOR-TENSION DEVICE.—The vapor-tension principle is also used to actuate some types of automatic control units. This is a common type of temperature-measuring device in which the effects of temperature changes are transmitted into motion by a highly volatile liquid. The most used vapor-tension device is the simple compressible bellows, like the one shown in figure 9-35.

This bellows is made of brass. It is partially filled with alcohol, ether, or other volatile liquid not corrosive to brass. When the temperature around the bellows increases, the heat gasifies the liquid inside and causes the bellows to extend. The extension closes a set of electrical contacts, as shown in figure 9-36. When the bellows cools



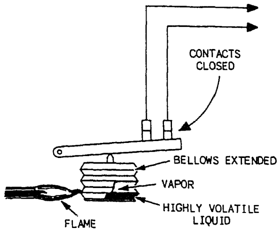
54.525

Figure 9-35.—A simple vapor-tension device.



54.524

Figure 9-34.—Various types of bimetallic strips.



54.525.1

Figure 9-36.—A pressure-tension device closing electrical contacts.

again, it contracts. The contraction opens the electrical contacts.

REMOTE-BULB DEVICE.—Liquid-filled devices are not always limited to the simple bellows. There are some remote-bulb devices that not only have a bellows but also have a capillary tube and a liquid-filled bulb, such as that shown in figure 9-37.

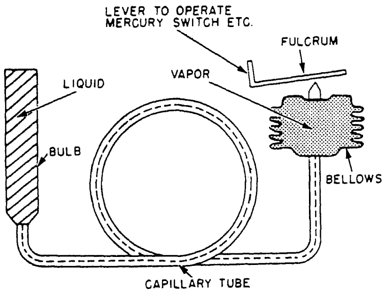
When the liquid in the bulb is heated, part of it gasifies and forces its way through the capillary tube into the bellows. This increased pressure inside the bellows causes it to extend and open a set of electrical contacts (or open or close a valve). When the bulb cools, the gas liquefies and decreases pressure inside the bellows. This decreased pressure allows the bellows to contract and close the electrical contacts.

Pressure-responsive devices are actuating mechanisms installed in units, such as steam-pressure controls, steam-pressure gauges, and pressure regulators.

BELLOWS.—One type of pressure-responsive actuating device uses bellows in a way similar to that of the remote-bulb type. In this application, the bellows extends and contracts in response to changes in steam pressure. The action caused by movement of the bellows opens or closes a set of electrical contacts.

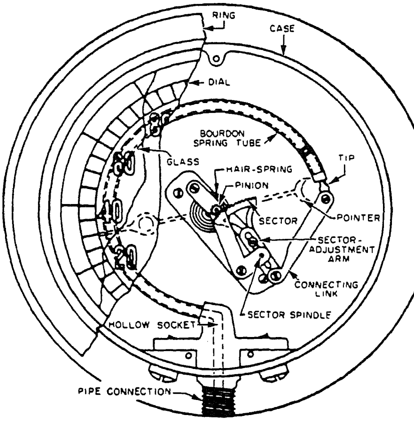
BOURDON TUBE.—Another type of pressure-responsive actuating device is found inside of the pressure gauge shown in figure 9-38. In this actuating device, the pressure is applied inside a hollow, partially flattened, bent tube, called a Bourdon spring tube. The pressure inside this tube tends to straighten it, and in so doing, it moves the lever mechanism that turns the pointer. The pressure gauge measures the pressure in pounds per square inch (psi).

Humidity-responsive devices open or close solenoid or motorized valves which control the flow of water or steam to humidifying equipment.



54.526

Figure 9-37.—Schematic of a remote-bulb device.



54.526.1

Figure 9-38.—A typical Bourdon spring tube.

The sensitive element which actuates the motion in this device consists of a group of human hairs. These hairs lengthen when the humidity is high and shorten when the humidity is low.

Accumulation of dust and grease on these hairs, while not damaging, may decrease the sensitivity of the controller. Consequently, the element should be cleaned periodically with a camel's-hair brush and clean ether. This cleaning should be followed by a complete wetting with distilled water.

ELECTRICAL SWITCHES.—Electrical switches in heating control equipment operate electrical circuits in response to signals from automatic control units. In other words, the actions initiated by devices responsive to temperature, pressure, and humidity changes open or close switch contacts. These, in turn, control the operation of the heating plant through electrical circuits. Switches may be either the snap-action type or the mercury type.

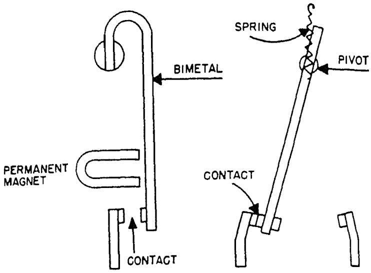
Snap-Action Type.—Snap-action switches vary in their designs. Some are constructed so they have an over-center spring arrangement that is designed so the movement of the actuating lever engages the spring and causes the switch to move with snap-action. The snap-action type of switch is shown in figure 9-39.

Another snap-action switch shown in figure 9-40 has a small magnet that causes the electrical contacts to remain firmly closed. It also provides the switch with the snap-action effect. The contacts of this switch must open or close quickly to avoid excessive arcing across the points. Arcing burns the contacting surfaces, which eventually causes switch failure.

Mercury Type.—A mercury switch has the electrical contacts and a small amount of mercury in a hermetically sealed short glass tube, such as that shown in figure 9-40. Tilting the switch causes the mercury inside the tube to cover or uncover the contacts. When the contacts are covered, the electrical circuit is completed.

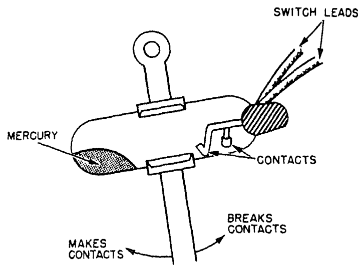
Every electrical switch is designed so it has a specific rated capacity in amperes and volts; for example, a capacity of 8 amperes at 110 volts. An electrical switch should never be overloaded because overloading causes overheating, which eventually results in switch failure that can create a fire hazard.

The standard controls furnished for automatic fuel-burning equipment come in sets designed for warm-air, hot-water, and steam-heating systems. A standard set usually consists of a thermostat, limit control, primary control, and electric motor. Auxiliary controls are those designed for a specific function in a warm-air, hot-water, or steam-heating system. They are in addition to the standard controls.



54.526.2

Figure 9-39.—A snap-action switch.



54.526.3

Figure 9-40.—A typical mercury switch.

THERMOSTAT.—The thermostat is the nerve center of the heating control system. It is the sensitive unit that responds to changes in room temperature. It indicates whether more or less heat is required from the heating plant. It transmits the indicating signal to a primary control for action. This indicating signal is initiated by closing or opening electrical contacts in the thermostat.

Thermostats often differ in construction according to the type of primary control with

which they are to be used. Probably the most used thermostats are the spiral-bimetallic type and the mercury-bulb type.

An electric clock thermostat has the additional features of an electric clock and an automatic mechanism that can be adjusted to change the thermostat setting at a desired time. For instance, it can be adjusted to reset the thermostat automatically from 80 °F to 60 °F at 11:00 p.m. (when 80 °F heat is not needed). Then, it will reset the thermostat to 80 °F at 6:00 a.m. (when more then 60 °F heat is needed).

The location for the thermostat should be representative of that part of the building in which heat is needed to maintain a comfortable temperature. The best location is on an inside wall, just a few feet from an outside wall and about 4 1/2 feet above the floor. The thermostat wiring must conform to local electrical ordinances.

To check the calibration of a thermostat, hang an accurate test thermometer within 2 inches of the device. Allow 15 to 30 minutes for the thermostat and thermometer to adjust themselves to room temperature. The thermostat contacts should close when the control knob or dial is set at the temperature indicated by the test thermometer. You should not try to recalibrate the thermostat if the closing point varies 1 °F or less. When calibration is necessary, follow the manufacturer's instructions.

FURNACE INSTALLATION

Since there are many types and makes of oil- and gas-fired warm-air furnaces on the market, detailed assembly instructions to suit all makes and types cannot be given in this manual. However, some general instructions, which apply to both oil-fired and gas-fired furnaces, except as noted, are given below.

Carefully follow assembling instructions included with each furnace or blower shipment. Each piece or casting is manufactured to fit in its proper place. Parts are seldom interchangeable.

Install furnaces in a level position. If the floor is uneven, use a steel wedge, a cast-iron wedge, or the leveling bolts provided on some equipment. Use a spirit level to make sure the unit is level.

Gas-fired and oil-fired forced-air units, which have the blower below the heating element or combustion chamber, should be set on masonry at least 3 inches thick and extending at least 12 inches beyond the casing wall. Install all other units on a cold masonry floor. Provide enough clearance to permit easy access for repairs. Make the clearance at least 18 inches from wood or other combustible material unless you install an asbestos board at least 1 inch from the combustible material. Units may be installed nearer to masonry walls; however, leave ample room to permit proper servicing.

Furnace cement is furnished with each cast-iron furnace. Seal all furnace joints with a liberal amount of furnace cement between sections to ensure the furnace is gastight. Asbestos rope is furnished with a number of furnaces; follow the manufacturer's instructions covering its use. See that projections from the furnace, such as the smoke pipe or cleanout doors, extend through the outside of the casing.

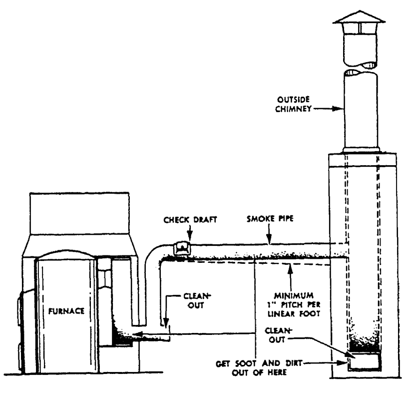
In assembling a furnace, be sure to tighten all bolts. Draw each bolt until it is almost tight. Then, after all bolts have been installed, draw each one gradually until all are uniformly and properly tight. Avoid drawing bolts too tight, as this can crack or break a casting or buckle a steel plate.

After assembling the furnace, check all doors for free operation and tight fit.

Install the downdraft diverters furnished with the equipment on all gas-burning furnaces. Diverters are developed for individual furnaces.

Use a vent or smoke pipe that is at least as large as the smoke-pipe outlet of the furnace.

Securely fasten the vent or smoke pipe at each joint with a minimum of three sheet metal screws. Install horizontal pipe with a pitch upward of at least 1 inch per linear foot. (See fig. 9-41.)



54.527

Figure 9-41.—Typical smoke pipe (flue) installation.

Ventilate the furnace room adequately to supply air for combustion. Provide an opening having 1 square inch of free-air area for each 1,000 Btu per hour of furnace input rating with a minimum of 200 square inches. Locate the opening at or near the floor line whenever possible. In addition, provide two louvered openings, each having a free-air area of at least 200 square inches in it, at or near the ceiling as near opposite ends of the furnace room as possible.

Tank installation is largely governed by local conditions. Listed here are the principles of tank installation that give greatest freedom from service problems. Adhere as closely to these recommendations as local conditions permit.

When possible, install single-pipe gravity oil feed on inside tanks or elevated outside tanks. (See fig. 9-42.) This type of installation is used for single-stage pumps. Use a 1/4-inch globe valve at the tank instead of a larger size. Larger valves sometimes cause tank hum.

For all installations, use a continuous piece of 1/2-inch copper tubing from the oil tank or valve to the burner and a similar piece for the return when required. The principle is to minimize the number of joints and thus minimize the possibility of air or oil leaks.

For inside installations where it is necessary to run the piping overhead between the tank and burner, when the burner is either above or below the tank level, the two-pipe system is recommended. This requires the use of a two-stage pump.

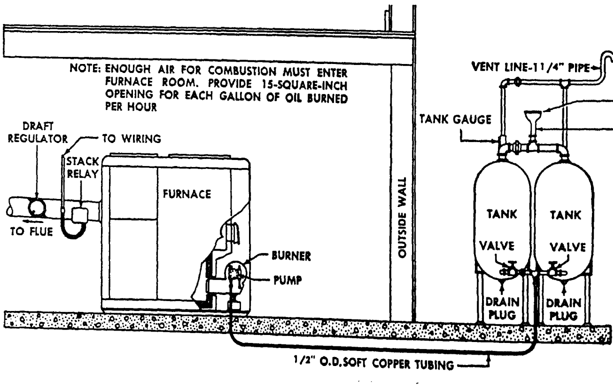
A dual-stage pump may be changed from a single-stage to a two-stage pump to accommodate a single-pipe or two-pipe system. The stages on a Webster fuel pump can be changed by removing the four screws on the pressure side of the pump and lining the Number 1 up with the letter *P* on the pump body for a one-pipe system. The Number 2 lined up with the letter *P* is for a two-pipe system. Most Sunstrand fuel pumps are shipped from the factory set up for a one-pipe system. To change to a two-pipe system, remove the 3/8-inch pipe plug from the bottom of the pump housing. There you will find an Allen head plug. Remove this plug for a two-pipe system.

Install the outside tanks (fig. 9-43) according to the instruction below.

Normally, when you are installing an underground fuel tank, the suction and return lines are made of black iron from the tank to the inside of the building, and there the burner is connected by copper tubing with a coil in it (not shown in the illustration) to eliminate vibration.

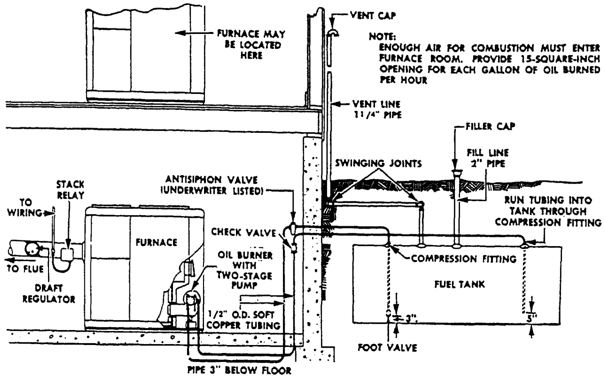
The return line is usually installed in the opposite end of the tank. Carry it to within 5 inches of the bottom. This creates an oil seal in the two lines, and any agitation caused by return oil is safely away from the suction line.

A 1 1/2-inch fill line and a 1 1/2-inch vent line are recommended. Carry the vent well



87.87

Figure 9-42.—Diagram of piping for inside or outside elevated tank installations.



87.88

Figure 9-43.—Diagram of piping for buried outside tank.

aboveground and put a weatherproof cap on it. Pitch the vent line down toward the tank.

Use special pipe dope on all iron pipe fittings that carry oil.

Treat the underground outside tank and piping with a standard preparation or commercial corrosion-resistant paint.

MAINTENANCE OF FUEL OIL SYSTEMS

Among the major duties of the Utilitiesman 2 are troubleshooting and servicing oil burners. To keep the burner in good operating condition, you must be able to recognize the symptoms of various types of trouble and must know how to make various service and maintenance adjustments to the burner.

Before getting into a discussion on troubleshooting and servicing of oil burners, let us point out some information on fuel oil firing.

FUEL OIL FIRING

Because fuel oils do not burn in the liquid state, several physical conditions must be attained to effect complete and efficient combustion.

1. Either the liquid must be thoroughly vaporized or gasified by heating within the burner, or it must be atomized by the burner so vaporization can occur in the combustion space.

2. The mist must be thoroughly mixed with sufficient combustion air.

3. Required excess air must be maintained at a minimum to reduce stack thermal loss.

4. Flame propagation temperature must be maintained.

Vaporization within the burner is generally confined to small domestic services, such as water heating, space heating, and cooking, and to some industrial processes. Burners for this purpose are usually of the pot type with natural or forced draft, gravity float-type feed control, and hand or electric ignition. Kerosene, diesel oils, and commercial oils of grades Nos. 1 and 2 are suitable fuels because they vaporize at relatively low temperatures.

If oil is to be vaporized in the combustion space in the instant of time available, it must be broken up into many small particles to expose as much surface as possible to the heat. This atomization is done in three basic ways:

1. By using steam or air under pressure to break the oil into droplets

2. By forcing oil under pressure through a suitable nozzle

3. By tearing an oil film into tiny drops by centrifugal force

Primary combustion air is usually admitted to the furnace through a casing surrounding the oil burner. The casing is spiral-vaned to impart a swirling motion to the air, opposite to the motion of the oil. Three types of burners used for atomization are the steam- or air-atomizing burner, the mechanical-atomizing burner, and the rotary-cup burner.

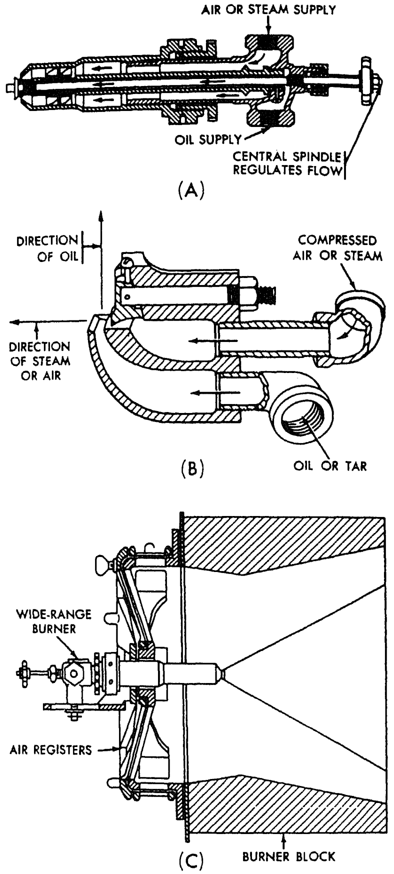
Burners should be piped with a circulating fuel line, including cutout, bypass, pressure-relief valves, and strainer, ahead of the burner. Burners should be accessible and removable for cleaning, and the orifice nozzle plates should be exchangeable to compensate for a wide range in load demand.

Steam-Atomizing and Air-Atomizing Burners

The burners consist of a properly formed jet-mixing nozzle to which oil and steam or air are piped. The conveying medium mixes with fine particles of fuel passing through the nozzle, and the mixture is projected into the furnace. Nozzles may be of the external or internal mixing type, designed to project a flame that is flat or circular and long or short. A burner should be selected to give the form of flame that is most suitable for furnace conformation. Nozzles should be positioned so there is no flame impingement on the furnace walls and so combustion is completed before the flame contacts the boiler surfaces.

Steam-atomizing burners are simpler and less expensive than the air-atomizing type and are usually used for locomotive and small power plants. They handle commercial-grade fuel oils Nos. 4, 5, and 6 and require a steam pressure varying from 75 to 150 psi. The oil pressure needs to be enough to carry oil to the burner tip, usually from 10 to 15 psi. Burners using air as the atomizing medium are designed for three air pressure ranges: low pressure to 2 psi, medium pressure to 25 psi, and high pressure to 100 psi.

Figure 9-44 shows a steam-atomizing burner of the external mixing type. In (A) the oil reaches the tip through a central passage and whirls against a sprayer plate to break up at right angles (B) to the stream of steam. The atomizing stream surrounds the oil chamber and receives a whirling motion from vanes in its path. When air is used as the atomizing medium in this burner, it should be at 10 psi for light oils and 20 psi for heavy oils. In (C) combustion air enters through a register; vanes or shutters are adjustable to give control of excess air.



75.297

Figure 9-44.—Steam-atomizing burner.

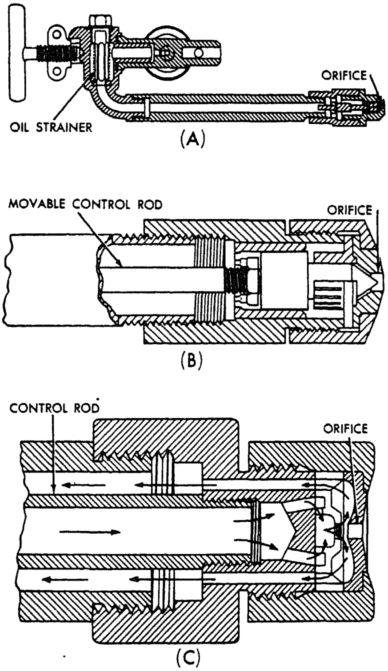
Mechanical-Atomizing Burner

The burner is universally used except in domestic or low-pressure service. Good atomization results when oil under high pressure (to 300 psi) passes through a small orifice and emerges as a conical mist. The orifice atomizing the fuel is often aided by a slotted disk that whirls the oil before it enters the nozzle.

Figure 9-45 shows a mechanical-atomizing burner. (A) is a cross section of the burner; (B) shows the central movable control rod that varies, through a regulating pin, the area of tangential slots in the sprayer plate and the volume of oil passing through the orifice; (C) shows a design with a wide-capacity range, obtained by supplying oil to the burner tip at a constant rate in excess of demand. The amount of oil burned varies with the load; the excess is returned.

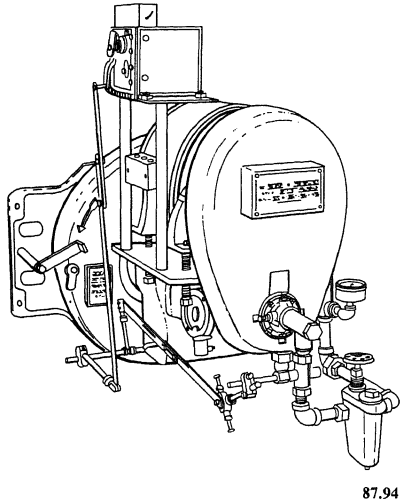
Horizontal Rotary-Cup Burner

The burner (fig. 9-46) atomizes fuel oil by tearing it into tiny drops. A conical or cylindrical cup rotates at high speed (about 3,450 rpm), if motor driven. Oil moving along this cup reaches the periphery where centrifugal force flings it into an airstream. It is suitable for small low-pressure boilers.



87.93

Figure 9-45.—Mechanical-atomizing burner.



87.94

Figure 9-46.—Rotary-cup oil burner.

OIL-BURNER MAINTENANCE

Before attempting to start or to service oil burners, see that you have the proper maintenance equipment available. One item of equipment needed is a pressure gauge set. This should consist of a 150 psi pressure gauge, fittings to connect it, and a petcock for removing the air from the oil line when starting the burner. You will need a full set of Allen setscrew wrenches for bypass plugs and for adjusting the nozzle holder and electrodes. Make sure you have a socket wrench of proper size for removing or replacing the nozzle, an open-end wrench as required for the nozzle holders, and a small thermostat wrench. This wrench comes packed with the thermostat and is used for adjusting the differential. A small screwdriver is required for adjusting pressure at the regulator and installing and servicing the thermostat. Another important item is pipe dope, and if available, use the oil-line type only. If in doubt, order a can of special oil-pipe dope for use on all pipe threads requiring dope. A nozzle assortment

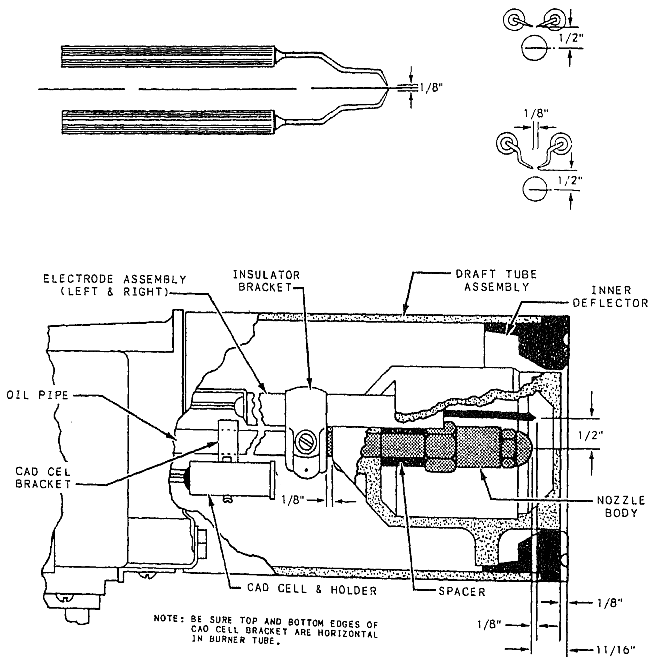
should also be kept on hand. It is cheaper to make a change, time considered, than to clean the nozzle on the job. When a few nozzles have accumulated, clean them in the shop.

When installing a nozzle, use a socket wrench for turning the nozzle. Be sure the nozzle seat is clean. Screw it on until it reaches the bottom, then back it off and retighten it several times to make sure of a tight oil seal. Do not over tighten the nozzle or the brass threads will become deformed, making it difficult to remove the nozzle.

Clean the nozzles in the shop on a clean bench. A nozzle is a delicate device. Handle it with care. Use kerosene or safety solvent to cut the grease and gum; use compressed air, if available, to blow the dirt out. Use goggles for eye protection when blowing dirt out with compressed air. Never use a metal needle to clean the opening; it will ruin the nozzle. Sharpen the end of a match or use a nonmetallic bristle brush to clean the opening.

When you are checking the nozzle, adjustments may have to be made in the distance of the nozzle from the tube end, the distance of the ignition points ahead of and above the nozzle, and the distance or gap between the ignition points. Figure 9-47 shows these nozzles adjustments. The nozzle tip is set 5/8 inch apart, 1/8 inch ahead of the nozzle, and 1/2 inch above the nozzle center line. These settings are given only for this particular illustration. Actual adjustments should always be made according to the specific settings in the manufacturer's instruction manual. Always tighten electrodes securely to ensure permanent adjustment.

When reinstalling either the pump or the motor, check the coupling to ensure there is no



87.89.1

Figure 9-47.—Setting of ignition points and nozzle.

end pressure on the pump shaft as evidenced by lack of end play. If there is end pressure, the coupling should be loosened, moved closer to the pump, and retightened.

TROUBLESHOOTING

Common operating difficulties and methods of correcting them are outlined below.

1. If the furnace pulsates on starting, on stopping, or during operation, check for—

a. Proper adjustments of the nozzle electrode assembly and blast tube in relation to each other and to the firebox.

b. Improper draft. Make sure there is no downdraft. Change the setting on the draft regulator if the draft is not strong enough. Check the chimney to be sure that there are no leaks that will cause a poor draft.

c. Defective nozzle. If it is defective, install a new nozzle.

d. Air in the line between the fuel unit and the nozzle. Air trapped here will be compressed during burner operation and will expand when the burner stops, causing oil to squirt out of the nozzle, accompanied by a bubbling sound. Waiting a few days to make final adjustments often allows time for trapped air to escape.

2. If the flame is raw and stringy, check for—

a. Too great an opening in the air adjustment. Adjust the volume of air.

b. Partly plugged nozzle. Install a new nozzle.

c. Air in the pump. If the pump contains air, vent it with the petcock on the pressure gauge.

3. If the ignition points collect carbon, check for—

a. Ignition points too close to the nozzle. Adjust.

b. Nozzle loose in the holder. Tighten the nozzle.

c. Improper oil cutoff when the burner is shut down. Check the pressure-regulating valve and clean if necessary.

4. If the oil pump is noisy, check for—

a. Air in the oil line. (This is the most common cause.) Remove the air by loosening the vent plug where the pressure gauge is attached.

b. Leaks in the suction line. Any leak in the overhead piping above the liquid level in the storage tank allows air to suck into the oil line.

c. Excessive suction on the oil line is due to a plugged strainer or to water condensed in the oil tank. Clean and change the filter, or drain or siphon the water from the tank, or both.

5. If the burner starts and stops too frequently, check for—

a. Thermostat is improperly wired. Be sure the thermal element in the room thermostat is screwed in tight. Check the wiring to determine whether the wires are reversed or spliced incorrectly.

b. Thermostat is not properly adjusted. Adjust according to instructions packed with the thermostat.

c. Drive arm adjustment is incorrect. Check the primary control or stack switch according to instructions packed with the unit.

d. Limit control is set too low. This will shut the burner off before the building can get warm.

e. Plugged air filters which cut off air circulation. This condition causes the burner to shut down on limit control. Change or clean the filters.

f. Nozzle is too large for the unit; heat buildup becomes too rapid. Install a nozzle of correct size.

6. Burner fail safe is activated (stack control has thrown the burner safety shutdown), check for—

a. Low voltage occurring at night. Check with a recording voltmeter for at least 24 hours and preferably longer.

b. Wrong polarity of wiring. If a hot line is connected where the ground should be, there is sometimes enough leakage through the control to cause a safety shutdown.

c. Primary control or stack switch improperly adjusted. Check all adjustments within this control according to the instruction sheet.

7. If there is no oil at the nozzle, check for—

a. Fuel too low in the supply tank.

b. Plugged nozzle. Install a new nozzle.

c. Leak in the suction line. Repair.

d. Leak in the vacuum-gauge port. Repair.

e. Pump failing to turn. Check motor, fuses, overload switch, wiring, and controls.

f. Leaking strainer gasket. Install a new gasket.

g. Leaking pump-shaft seal. Install a new seal.

Table 9-1.—Oil Pump Troubleshooting

OIL PUMP TROUBLESHOOTING		
CONDITION	CAUSE	REMEDY
NO OIL FLOW AT NOZZLE	Oil level below intake line in supply tank	Fill tank with oil.
	Clogged strainer or filter	Remove and clean strainer. Replace filter element.
	Clogged nozzle	Replace nozzle.
	Air leak in intake line	Tighten all fittings in intake line. Tighten unused intake port plug. Check filter cover and gasket.
	Restricted intake line (High-vacuum reading)	Replace any kinked tubing and check any valves in intake line.
	A two-pipe system that becomes air bound	Check for and insert bypass plug. Make sure return line is below oil level in tank.
	A single-pipe system that becomes air bound	Loosen gauge port plug or easy flow valve and bleed oil for 15 seconds after foam is gone in bleed hose. Check intake line fitting for tightness. Check all pump plugs for tightness.
	Slipping or broken coupling	Tighten or replace coupling.
	Frozen pump shaft	Replace pump.
OIL LEAK	Loose plugs or fittings	Dope with good quality thread sealer. Retighten.
	Leak at pressure adj. screw or nozzle plug	Washer may be damaged. Replace the washer or O-ring.
	Blown seal (single-pipe system)	Check to see if bypass plug has been left in unit. Replace oil pump.
	Blown seal (two-pipe system)	Check for kinked tubing or other obstructions in return line. Replace oil pump.
	Seal leaking	Replace oil pump.
	Cover	Tighten cover screws or replace damaged gasket.
NOISY OPERATION	Bad coupling alignment	Loosen fuel unit mounting screws slightly and shift fuel unit in different positions until noise is eliminated. Retighten mounting screws.
	Air in inlet line	Check all connections. Use only good flare fittings.
	Tank hum on two-pipe system and inside tank	Install return line hum eliminator in return line.
PULSATING PRESSURE	Partially clogged strainer or filter	Remove and clean strainer. Replace filter element.
	Air leak in intake line	Tighten all fittings.
	Air leaking around cover	Be sure strainer cover screws are tightened securely. Check for damaged cover gasket.
IMPROPER NOZZLE CUT-OFF	To determine the cause of improper cutoff, insert a pressure gauge in the nozzle port of the fuel unit. After a minute of operation, shut burner down. If the pressure drops from normal operating pressure and stabilizes, the fuel unit is operating properly and air is the cause of improper cutoff. If, however, the pressure drops below 80 psig, oil pump should be replaced.	
	Filter leaks	Check face of cover and gasket for damage.
	Strainer cover loose	Tighten four screws on cover.
	Air pocket between cutoff valve and nozzle	Run burner, stopping and starting unit, until smoke and after-fire disappears.
	Air leak in intake line	Tighten intake fittings. Tighten unused intake port and return plug.
	Partially clogged nozzle strainer	Clean strainer or change nozzle.
	Leak at nozzle adapter	Change nozzle and adapter.

h. Fuel unit not operating. Loosen the vent plug in the fuel unit (dump) and see whether the fuel is being delivered far enough. If the fuel is not being delivered at the fuel unit, return it to the shop for repair.

FLAME ADJUSTMENT

After the burner has been visually adjusted and allowed to run about 30 minutes, reduce the stack draft until there is just enough over-fire draft in the firebox to keep the pressure from increasing under unfavorable draft conditions. The draft regulator helps maintain a constant draft in the furnace regardless of outside weather conditions. Adjust the draft by properly setting the adjuster. Too little draft is likely to cause firebox pressure, odors in the building, and possible smoke or smothering of the flame. Too much draft accentuates the effect of a possible leak in the furnace, lowers the percentage of CO_2 in the flue gas, and, in turn, reduces the overall efficiency of the unit. After the burner flame and draft are properly adjusted, a flue-gas analysis should show a CO_2 content of approximately 10 percent. If it does not, recheck the burner air adjustment and inspect for air leaks. For best results, the flame should be just large enough to heat the building properly in cold weather.

Air supplied to the burner will then be the minimum for clean combustion. If the furnace is large enough and the burner has been set for correct oil flow and minimum amount of air, stack temperature should not exceed 600°F. Higher stack temperatures indicate that the fire is too large or the furnace too small, or that there is too much excess air.

TEST EQUIPMENT

It is almost impossible to set and adjust a burner without instruments or test equipment. Proper instruments, in good working order, must be available in the heating shop for use by personnel who service this equipment.

The draft gauge, usually of the pointer-indicating type, is used to determine suction in the smoke pipe or combustion chamber. Suction is measured in inches of water. Carefully follow the instructions for operating the instrument.

The stack thermometer is used to indicate the temperature of gases in the smoke pipe. Insert the thermometer halfway between the center and outside of the smoke pipe and not more than 12 inches from the furnace between the smoke pipe connection and the draft regulator or barometric damper. Be careful to prevent the thermometer from being influenced by cold air taken in by the draft regulator.

The flue-gas analyzer is used to determine the percentage of CO_2 produced by combustion. The CO_2 reading shows how much excess air is being used. Along with the stack temperature, it denotes the efficiency of the furnace. If, despite a good flame setting, CO_2 readings are low, examine the furnace for air leaks.

FUEL PUMP

Maintenance requirements include cleaning the strainer, servicing the valve seat and needle valve, and adjusting the pressure regulator. Strainers must be cleaned frequently to prevent the screen from clogging and causing a shutdown. A good test for valve operation consists of removing the nozzle line at the pump connection, starting and stopping the pump, and observing whether the valve cuts off sharp and lean. When necessary, the valve is easily serviced by removing the valve chamber cover, holding spring, washer, adjusting spring, cap, and bellows assembly. Then, by taking off the nut that is marked "Nozzle," the valve, valve guide, and plug assembly can be removed.

Adjustment of the pressure regulator can be done by replacing the vent plug with a pressure gauge, removing the cover screw, and using an Allen wrench to turn the adjusting screw clockwise to increase the pressure or counterclockwise to decrease the pressure.

Burner failure or improper unit operation can be caused by various problems. Often the problem can be pinpointed by observing the type of failure and giving it some thought before attacking the problem. At other times, the cause can only be determined by a process of elimination. Table 9-1 lists specific oil pump troubleshooting procedures, while table 9-2 lists general oil burner troubleshooting procedures. Check the simplest and more obvious items before progressing to the other checks.

REFERENCES

Cleaver-Brooks Operation, Service, and Parts Manual, Nos. 750-90 and 750-91, Cleaver-Brooks Division of Aqua-Chem Inc., Milwaukee, Wisc., 1983.

Unit Information Service Manual, Lennox Industries Inc., Dallas, Tex., 1980.

Table 9-2.—Oil Burner Troubleshooting

TROUBLE	SOURCE	PROCEDURE	CAUSES	CORRECTION
BURNER FAILS TO START	Thermostat	Check thermostat settings.	Thermostat in "Off" or "Cool"	Switch to "Heat"
			Thermostat set too low	Turn thermostat to higher temp.
	Safety Overloads	Check burner motor, primary safety control, and auxiliary limit switch.	Burner motor overload tripped	Push motor overload reset button
			Primary control tripped on safety	Reset safety switch lever
			Auxiliary limit switch tripped on safety	Push auxiliary limit switch reset button
	Power	Check furnace disconnect switch and main disconnect switch.	Switch open	Close switch
			Blown fuse or tripped breaker	Replace fuse or reset breaker
	Thermostat	Touch jumper wire across thermostat terminals on primary control. If burner starts, then fault is in thermostat circuit.	Broken or loose thermostat wires	Repair or replace wires
			Loose thermostat screw connection	Tighten connection
			Dirty thermostat contacts	Clean contacts
			Thermostat not level	Level thermostat
			Faulty thermostat	Replace thermostat
	Cad Cell	Disconnect flame detector wires at primary control. If burner starts, fault is in detector circuit.	Flame detector leads shorted	Separate leads
			Flame detector exposed to light	Seal off false source of light
			Short circuit in flame detector	Replace detector
	Primary Control	Place trouble light between the black and white leads. No light indicates no power to the control.	Primary or auxiliary control switch open	Check dial adjustment. Set to maximum stop setting.
				Jumper terminals; if burner start switch is faulty, replace control.
			Open circuit between disconnect switch and limit control	Trace wiring and repair or replace
			Low line voltage or power failure	Call power company
		Place trouble light between the orange and white leads. No light indicates control faulty.	Defective internal control circuit	Replace control
	Burner	Place trouble light between the black and white leads to burner motor. No light indicates no power to burner motor.	Blown fuse	Replace fuse
		Place trouble light between the black and white leads to burner motor. Light indicates power to motor and a burner fault.	Binding burner blower wheel	Turn off power and rotate blower wheel by hand. If seized, free wheel from binding or replace fuel pump
			Seized fuel pump	
			Defective burner motor	Replace motor

Table 9-2.—Oil Burner Troubleshooting—Continued

TROUBLE	SOURCE	PROCEDURE	CAUSES	CORRECTION
BURNER STARTS BUT NO FLAME IS ESTABLISHED	Oil Supply	Check tank gauge or use dipstick.	No oil in tank	Fill tank
		Coat dipstick with litmus paste and insert to bottom of tank.	Water in oil tank	If water depth exceeds 1", pump out water or drain out
		Listen for pump whine.	Tank shutoff valve closed	Open valve
	Oil Filters and Oil Line	Listen for pump whine.	Oil line filter plugged	Replace filter cartridge
			Kinks or restriction in oil line	Repair or replace oil line
			Plugged fuel pump strainer	Clean strainer or replace pump
		Open bleed valve or gauge port. Start burner. No oil or milky oil indicates loss of prime.	Air leak in oil supply line	Locate and correct leak
				Tighten all connections
	Oil Pump	Install pressure gauge on pump and read pressure. Should not be less than 100 psig.	Pump partially or completely frozen—No pressure and motor locks out on overload	Replace pump
			Coupling disengaged or broken—No pressure	Reengage or replace coupling
			Fuel pressure too low	Adjust pressure to 100 psig
	Nozzle	Disconnect ignition leads. Observe oil spray (gun assembly must be removed from unit). Inspect nozzle for plugged orifice or carbon buildup around orifice.	Nozzle orifice plugged	Replace nozzle with same size, spray angle, and spray type
			Nozzle strainer plugged	
			Poor or off center spray	
	Ignition Electrodes	Remove gun assembly and inspect electrodes and leads.	Fouled or shorted electrodes	Clean electrodes and leads
			Dirty electrodes and leads	
			Eroded electrode tips	Dress up electrode tips and reset gap to 1/8" and correctly position the tips
			Improper electrode gap spacing	
			Improper position of electrode tips	
			Bad buss bar connection	Retension and align
			Cracked or chipped insulators	Replace electrode
			Cracked or burned lead insulators	Replace electrode leads
	Ignition Transformer	Connect ignition leads to transformer. Start burner and observe spark. Check line voltage to transformer primary.	Low line voltage	Check voltage at power source. Correct cause of voltage drop or call power company
			Burned out transformer windings	Replace transformer
			No spark or weak spark	Properly ground transformer case
	Burner Motor	Motor does not come up to speed and trips out on overload. Turn off power and rotate blower wheel by hand to check for binding or excessive drag.	Low line voltage	Check voltage at power source. Correct cause of voltage drop or call power company
			Pump or blower overloading motor	Correct cause of overloading
			Faulty motor	Replace motor

Table 9-2.—Oil Burner Troubleshooting—Continued

TROUBLE	SOURCE	PROCEDURE		CAUSES	CORRECTION
BURNER STARTS AND FIRES BUT LOCKS OUT ON SAFETY	Poor Fire	After burner fires, immediately place jumper across flame detector terminals at primary control.	If burner continues to run, fault may be due to poor fire. Inspect fire.	Unbalanced fire	Replace nozzle
				Too much air—lean short fire	Reduce combustion air—check combustion
				Too little air—long dirty fire	Increase combustion air—check combustion
				Excessive draft	Adjust barometric damper for correct draft
				Too little draft or restriction	Correct draft or remove restriction
	Flame Detector		If fire is good, fault is in flame detector. Check detector circuit.	Dirty cad cell face	Clean cad cell face
				Faulty cad cell—exceeds 1,500 Ohms	Replace cad cell
				Loose or defective cad cell wires	Secure connections or replace cad cell holder and wire leads
	Primary Control		If burner locks out on safety, fault is in primary control.	Primary control circuit defective	Replace primary control
BURNER STARTS, FIRES BUT LOOSES FLAME AND LOCKS OUT ON SAFETY	Poor Fire	After burner fires, immediately place jumper across flame detector terminals at primary control.	If burner continues to run (does not lock out on safety), fault may be due to poor fire (marginal). Inspect fire.	Unbalanced fire	Replace nozzle
				Too much air—lean short fire	Reduce combustion air—check combustion
				Too little air—long dirty fire	Increase combustion air—check combustion
				Excessive draft	Adjust barometric damper for correct draft
				Too little draft or restriction	Correct draft or remove restriction
	Flame Detector		If fire is good, fault is in flame detector. Check detector circuit.	Dirty cad cell face	Clean cad cell face
				Faulty cad cell—exceeds 1,500 Ohms	Replace cad cell
				Loose or defective cad cell wires	Secure connections or replace cad cell holder and wire leads
	Oil Supply		If burner looses flame (does not lock out on safety), fault is in fuel system.	Pump looses prime—air slug	Prime pump at bleed port
				Pump looses prime—air leak in supply line	Check supply line for loose connections and tighten fittings
				Water slug in line	Check oil tank for water (over 1"), pump out water, or drain out
				Partially plugged nozzle or nozzle strainer	Replace nozzle
		Listen for pump whine.		Restriction in oil line	Clear restriction
				Plugged fuel pump strainer	Clean strainer or replace pump
				Cold oil—outdoor tank	Change to number 1 oil

Table 9-2.—Oil Burner Troubleshooting—Continued

TROUBLE	SOURCE	PROCEDURE	CAUSES	CORRECTION
BURNER STARTS AND FIRES BUT SHORT CYCLES (TOO LITTLE HEAT)	Thermostat	Check thermostat.	Heat anticipator set too low	Correct heat anticipator setting
			Vibration at thermostat	Correct source of vibration
			Thermostat in warm-air draft	Shield thermostat from draft or relocate thermostat
	Limit Control	Connect voltmeter between line voltage connections to primary control (black and white leads). If burner cycles due to power interruption, it is cycling off limit.	Dirty air filters (furnace)	Clean or replace filter
			Blower running too slow	Speed up blower for 85° to 95° temperature rise
			Blower motor seized or burned out	Replace motor
			Blower bearings seized	Replace bearings and shaft
			Blower wheel dirty	Clean blower wheel
			Blower wheel in backwards	Reverse blower wheel
			Wrong motor rotation	Replace with motor of correct rotation
			Restrictions in return air or supply air system	Correct cause of restriction
			Adjustable limit control set too low	Reset limit to maximum stop setting
	Power	If voltage fluctuates, then fault is in power source. Recheck voltage at power source.	Loose wiring connection	Locate and secure connection
			Low or fluctuating line voltage	Call power company
BURNER RUNS CONTINUOUSLY (TOO MUCH HEAT)	Thermostat	Disconnect thermostat wires at primary control. If burner turns off, fault is in thermostat circuit.	Shorted or welded thermostat contacts	Repair or replace thermostat
			Stuck thermostat bimetal	Clear obstruction or replace thermostat
			Thermostat not level	Level thermostat
			Shorted thermostat wires	Repair short or replace wires
			Thermostat out of calibration	Replace thermostat
			Thermostat in cold draft	Correct cause of draft or relocate thermostat
	Primary Control	If burner does not turn off, fault is in primary control	Defective primary control	Replace primary control

Table 9-2.—Oil Burner Troubleshooting—Continued

TROUBLE	SOURCE	PROCEDURE		CAUSES	CORRECTION
BURNER RUNS CONTINUOUSLY (TOO LITTLE HEAT)	Combustion	Check burner combustion for CO_2 stack temperature and smoke.	Low CO_2 less than 8%.	Too much combustion air	Reduce combustion air
				Air leaks into heat exchanger around inspection door, etc.	Correct cause of air leak
				Excessive draft	Adjust barometric damper for correct draft
				Incorrect burner head adjustment	Correct burner head setting
			High smoke reading more than No. 1 smoke.	Dirty or plugged heat exchanger	Clean heat exchanger
					Readjust burner
				Insufficient draft	Increase draft
				Incorrect burner head adjustment	Correct burner head setting
				Too little combustion air	Increase combustion air
			High stack temperature more than 550 °F Net.	Too little blower air	Speed up blower to 85° to 95° temperature rise
				Blower belt too loose and slipping	Tighten blower belt
				Dirty or plugged heat exchanger	Clean heat exchanger
				Dirty blower wheel	Clean blower wheel
				Dirty air filter (furnace)	Clean or replace filter
				Restricted or closed registers or dampers	Readjust registers or dampers
	Nozzle and Oil Pressure	Inspect fire, check nozzle size, and check oil pressure.		Partially plugged or defective nozzle	Replace nozzle
				Nozzle too small	Increase nozzle size
				Oil pressure too low (less than 100 psig)	Increase oil pressure to 100 psig

CHAPTER 10

HOT-WATER HEATING SYSTEMS

Learning Objective: Identify the procedures for installing, operating, maintaining, and troubleshooting hot-water heating systems; recognize the safety characteristics of steam and hot-water heating systems.

Hot water is a useful carrier of heat. Circulating in a closed system, the water absorbs heat in a boiler or heat exchanger and releases it to the heat-using equipment. Although the hot-water system does not replace the warm-air system we discussed in chapter 9, it has many advantages over the warm-air system. Air is not the most efficient heat-carrying medium; both hot water and steam carry more heat than air. Like air, water and steam may be heated at a central source and carried throughout the building in pipes. But unlike air, the water and steam are never open to the atmosphere. The hot-water system, then, is better for buildings, such as hospitals, where the air may be contaminated and should be circulated as little as possible.

All hot-water heating system installations of similar type, open gravity, closed-forced circulation, and the like, are similar in design and operating principle. However, details of installation, such as location of expansion tank, pumps, valves, venting, and protective devices, may vary considerably. It is important for new operators to check the details of existing installations. Proper understanding of the location and purpose of the equipment and controls eliminates unnecessary damage and equipment failure.

This chapter contains material on installing, maintaining, repairing, and troubleshooting of hot-water heating systems and solar radiation.

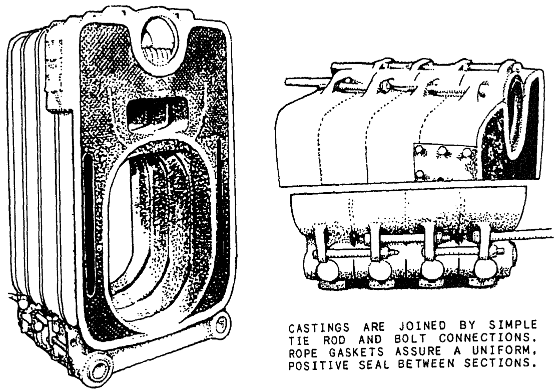
DOMESTIC HOT-WATER HEATING AND HOT-WATER BOILERS

The Navy uses both cast-iron and steel hot-water boilers as sources of heat for domestic hot-water systems in residences and other buildings. Small hot-water heaters heat the hot water for domestic and for limited industrial uses.

Hot-water boilers come in many shapes and sizes. They are constructed with a firebox for burning fuel and have provisions for passing the hot gases over the heat-absorbing surfaces of the boiler. In most cases, baffles guide the gases over the most effective route. These baffles also retard the flow of the gases from the furnace, so water can absorb as much of the heat as possible. Both ends of the boiler have openings for cleaning the boiler tubes and for washing the interior of the boiler. Since most boilers are stationary units permanently installed at the site, they have specified fittings and accessories for a specific heating job. Some boilers, however, called package boilers, are complete units, including fittings and accessories. These boilers are normally mounted on skids so they can be moved to different sites.

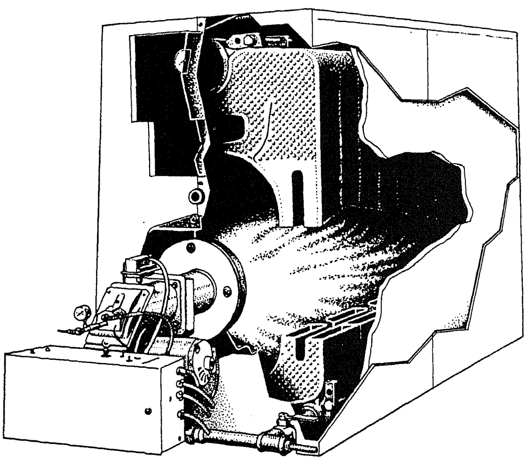
This accounts for the term *package boiler*. Package boilers usually have the same accessories and controls as the comparable stationary type of hot-water or steam boiler. Cast-iron boilers are seldom used as package boilers because of the danger of cracking the boiler sections during transportation.

Cast-iron hot-water boilers vary in size from small domestic units to moderately sized units capable of developing 31 through 98 horsepower. These boilers are usually constructed of several sections joined together by push nipples (round pieces of metal pipe tapered at both ends). The boiler sections are ordinarily



54.600

Figure 10-1.—Cast-iron boiler castings.

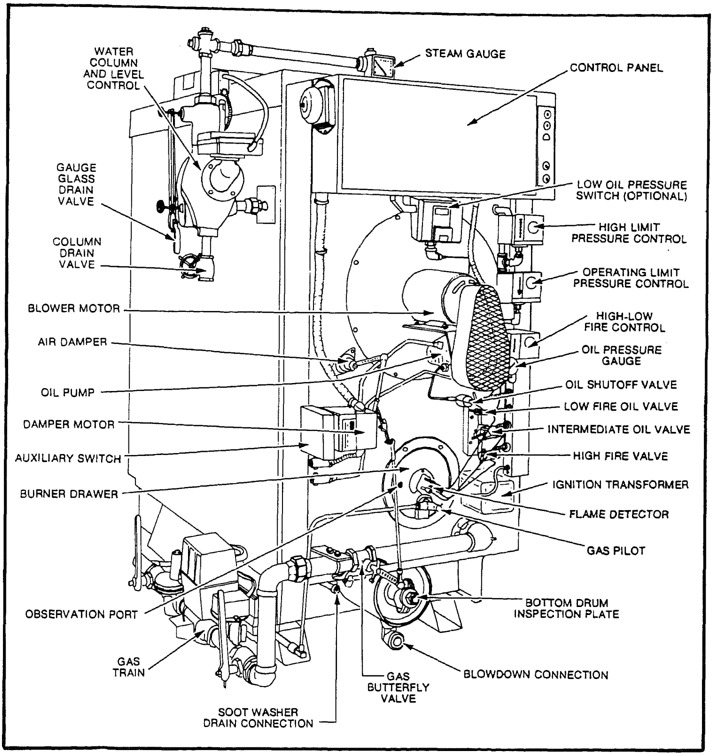


54.601

Figure 10-2.—Cutaway view of a cast-iron boiler.

connected by pipes known as header connections. (See fig. 10-1.)

Cast-iron boilers normally do not have brick settings. Usually, the only bricks used with these boilers are those that are sometimes used as a base for the boilers. In most cases, the bases are made of cast iron. Square sectional cast-iron boilers are similar to the typical unit shown in figure 10-2. This boiler consists of a front and rear section and a number of intermediate sections, depending on the size of the boiler. The sections are connected on each side at the top and bottom either by push nipples or by an outside header. When nipples are



54.602

Figure 10-3.—Typical hot-water boiler—light oil or gas fired.

used, these sections are held firmly together by rods and nuts.

The boiler has a separate base that does not contain water and, therefore, requires a floor of fireproof construction. Boilers that have water in their bases are referred to as wet-bottom boilers. These boilers are relatively small water units that may be installed on floors constructed of combustible materials. This method of installation, however, is not desirable.

The construction of square sectional boilers is ordinarily such that the sections can be taken through regular sized doors for assembly inside the boiler room. This is a distinct advantage from the standpoint of both installing new equipment and replacing broken sections. Cast-iron boilers resist the chemical action of corrosive agents much better than steel boilers.

The disadvantage of cast-iron hot-water heating boilers is the danger of the sections cracking or breaking when improperly handled or fired.

STEEL HOT-WATER BOILERS

Most steel hot-water boilers are constructed in two sections. One section consists of the water jackets, combustion chamber, and smoke passages. These components are either welded or riveted together as a unit. The other section consists of the base and either the grates or burner and is constructed according to the type of fuel used. (See fig. 10-3.)

Another steel boiler is a horizontal unit of the portable type, having an internal firebox surrounded by water lanes. It rests either on a cast-iron or a brick base. The front part of the boiler rests on a pedestal. A disadvantage of this one-piece steel boiler is that it is heavy and requires special equipment to lift it.

INSTALLING BOILERS FOR HOT-WATER HEATING

A boiler must have a good foundation. The top surface of the foundation should be level to ensure proper alignment of the boiler sections, and thus eliminate strain on the boiler castings. The furnace foundation should be poured separately from the finished floor. It should be of sufficient width and depth to support the boiler without any settling, and it should extend 2 inches above the finished floor. Assembly procedures vary in detail for various boilers. However, manufacturers furnish detailed procedures for the assembly of their boilers. Usually, the plans for the foundations can be procured from them.

OPERATION OF HOT-WATER BOILERS

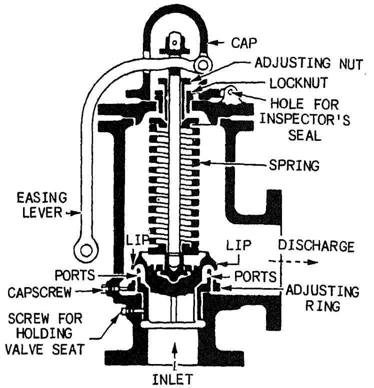
Hot-water boilers, regardless of their design and type, operate on the same basic principle. The fuel burns in the combustion chamber and produces heat. The resultant heat is radiated and conducted to the water in the water jackets surrounding the combustion chambers and passes through the boiler tubes; heat is liberated by the flue gases and absorbed by the water surrounding the tubes. The amount of heat transferred into the water depends on the rate of heat conduction through the metal in the boiler tubes and the rate of water circulation in the boiler. For this reason, boilers are designed with baffles to hold the hot gases as long as possible. They give up maximum heat before passing into the chimney.

BOILER FITTINGS AND ACCESSORIES

All boilers have certain accessories for safety and ease of operation. These accessories are pressure-relief valves, pressure gauges, water-level control valves, and automatic controls.

Pressure-Relief Valve

In a closed hot-water heating system, there is always the possibility of building up a dangerous



54.529

Figure 10-4.—A typical pressure-relief valve.

pressure. Consequently, a pressure-relief valve is installed to allow this pressure to escape. A typical pressure-relief valve is shown in figure 10-4. This valve is usually on the top of the boiler. It contains a spring-loaded valve that unseats when the pressure in the system increases to a predetermined value, thereby allowing water to escape until the pressure drops to a safe point. A valve of this type can be adjusted for different pressure.

Pressure-relief valves may eventually corrode and stick if they are not forced to operate occasionally. It is a good practice, once each month, to increase the pressure to a point that operates the valve. When the relief pressure on the gauge exceeds the setting of the valve, check the valve pressure with an accurate gauge and adjust it to the required amount. However, do not exceed the maximum safe pressure of the boiler.

Pressure Gauge

The operator must know the water pressure in the boiler at all times. A gauge is connected to the top of the boiler. It shows the water pressure in the boiler and in the system in pounds per square inch. This gauge is usually a combination gauge that also indicates boiler water temperature and altitude. The type shown in figure 10-5, however, indicates pressure only.

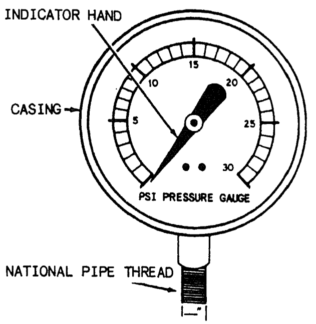


Figure 10-5.—A typical water pressure gauge.

Little maintenance is required for this unit, other than to clean the glass so the gauge can be read. Some types of pressure gauges are constructed so they can be recalibrated. However, the proper equipment to do this is not always available in the heating shop. To calibrate a pressure gauge properly, you must have either a master gauge set or a deadweight tester.

Water-Level Control Valve

Water is added to a hot-water heating system by either a manually operated water valve or an automatic valve, which is controlled by a float mechanism. Both valves are nearly identical to those used in the free-water system of a steam boiler.

Airflow Switch

The airflow switch, or "sail switch" as it is sometimes called, is in the stack, breeching, or the air inlet to the boiler. This switch shuts down the firing equipment in the event of an induced or forced draft failure. To check the operation of this switch, you restrict or shut off the draft. When you have done this, the switch should shut off the burning equipment.

HOT-WATER HEATING DISTRIBUTION SYSTEMS

In hot-water heating systems, the water is heated at a central source and circulated through pipes to radiators, convectors, or unit heaters. There are two general types of low-temperature, hot-water heating systems. The first type is a gravity system in which water circulation depends upon the weight difference between the hot column of water leading to the radiators and the relatively cooler, heavier column of water returning from the radiators. The second type is the forced-circulation system in which water is circulated by a power-driven pump.

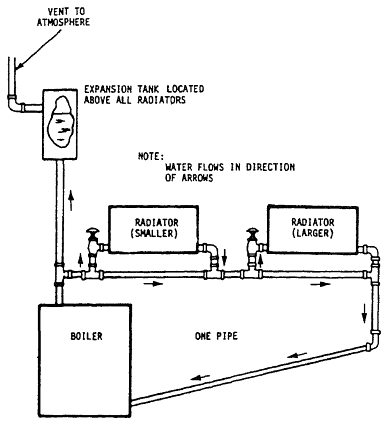
GRAVITY HOT-WATER DISTRIBUTION SYSTEM

The distribution systems and piping for hot-water heating systems and for domestic hot-water supply systems are simpler in design than those for steam because there are no traps, drips, or reducing valves. Several items, such as supports, insulation, and some valves and fittings, are the same for steam and hot-water distribution.

Gravity hot-water distribution systems operate because of the gravitational pull on the heavier cool water which sinks as the heated water becomes lighter and rises. At this point, some of the types of gravity systems that are currently used are discussed.

One-Pipe, Open-Tank Gravity Distribution System

The one-pipe, open-tank gravity distribution system shown in figure 10-6 consists of a single



54.530

Figure 10-6.—A one-pipe, open-tank gravity hot-water distribution system.

distribution pipe that carries the hot water to all of the convectors or radiators and returns it to the boiler. This system is easy to install and moderate in cost.

The water that flows into the radiators at the end of the system has a lower temperature than the water entering the first radiators. A system of this type should be designed so the water reaching the last convector is not too much cooler than the water reaching the first convector. Because of this progressive temperature drop in the distribution system, convector radiators should be installed at the end of the system to equalize the amount of heat radiation per radiator. It is difficult to get enough circulation by gravity to give the system small convector temperature drops; consequently, we do not recommend the one-pipe, open-tank gravity system.

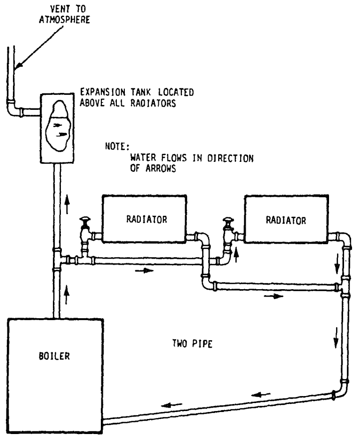
Two-Pipe, Open-Tank Gravity Distribution System

Many hot-water gravity distribution systems are two-pipe, open-tank systems, such as the one shown in figure 10-7. This heating system is constructed with separate water mains for supplying hot water and returning cold water. The radiators are connected in parallel between the two mains. In the two-pipe, open-tank gravity system, the distributing supply mains are either in the basement with upfeed to the radiators or in the attic. When the system is in the attic, it has overhead downfeed supply risers. The return mains are in the basement. Return connections for the two-pipe system are usually made into a gravity return, which pitches downward to the return opening in the heating boiler. The water temperature is practically the same in all radiators, except for the allowance to be made for the temperature drop in the distribution supply mains occurring between the boiler and the end of the circuit. Water temperatures are the lowest at the end of the circuit. The amount of temperature drop between the beginning and the end of the line depends upon the length of the main and upon the heating load.

A tank with its vent open to the atmosphere is installed in the system above the highest radiator for water expansion. The water level in the expansion tank rises and falls as the system is heated and cooled, and the system is full of water and free from air at all times. In the open-tank gravity hot-water heating system, the expansion tank is installed on a riser directly above the boiler, so the air liberated from the boiler water enters the tank and is not retained in the system.

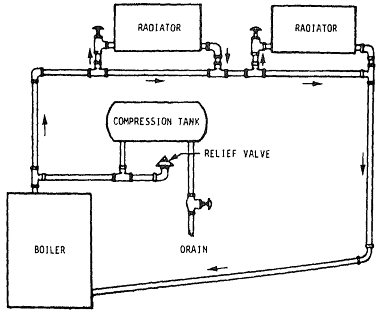
One-Pipe, Closed-Tank Distribution System

A one-pipe, closed-tank gravity hot-water distribution system, like the one shown in figure 10-8, is similar to the one-pipe, open-tank



54.530.1

Figure 10-7.—A two-pipe, open-tank gravity hot-water distribution system.



54.530.2

Figure 10-8.—A typical one-pipe, closed-tank distribution system.

gravity hot-water heating system, except the expansion tank is a pneumatic compression tank not open to the atmosphere. When the water in a closed-tank system is heated, it expands into the pneumatic compression tank. This action permits system operation at a much higher water temperature, without boiling, than the temperature in the one-pipe, open-tank gravity system. This also results in higher heat emission from the radiators.

A gravity open-tank system with an average boiler water temperature of 170 °F has a radiator emission rate of 150 Btu psi, whereas a gravity closed-tank system with an average boiler water temperature of 190 °F has a radiator emission of 180 Btu per square foot (psf). Higher boiler water temperatures permit higher temperature drops through the radiators; consequently, smaller pipe sizes can be used. The closed pneumatic compression system requires a relief valve, usually set for the relief of water pressure over 30 psi, depending upon the height of the building. A pressure-regulating valve automatically maintains the system full of water. Installation of the radiators and piping for an equivalent two-pipe, closed-tank gravity upfeed or overhead downfeed system is the same as that for the open system, except the sizes of both the pipe and the radiators are uniform and can be smaller. The open-tank system may have a reversed return main that does not go directly back to the boiler.

It doubles back from the last radiator and parallels the supply main back to the boiler entrance. The reversed return system allows equal length of heating circuits for all radiators. Friction and temperature losses for all radiators are nearly equal. In most cases, the reversed return system involves no more piping than other piping arrangements. With the correct size of piping and radiator supply tappings, the reversed return system provides even heat and circulation to all radiators, even those near the end of the circuit.

Expansion in a Gravity Hot-Water Distribution System

In the gravity and forced-circulation systems, open and closed expansion tanks allow the water in the distribution system to expand as the temperature rises. An open tank must be mounted at the highest point in the system; a closed tank can be located at any point. If the air cushion leaks out of the closed expansion tank, it fills with water. At times, you must recharge the tank by draining part of the water out of the tank and allowing air to fill the space.

In the open system, an expansion tank open to the atmosphere allows the system to expand. The open system is normally designed to operate at the maximum boiler temperature of 180 °F. This gives an average radiator temperature of 170 °F, or a radiator output of 150 Btu psf. The closed system, in which the expansion takes place against a cushion of air in the tank closed against the atmosphere, can be operated at temperatures above 212 °F because the pressure built up in the system prevents the water from boiling. Radiator temperatures then become equal to those of low-pressure steam systems.

When a hot-water system is first filled with water, it is normally necessary to bleed the air out of the system at the same time. You can remove the air by opening an air vent on a radiator or by breaking a union near the end of the line. The temperature of the water distributed is from 150 °F to 250 °F. The higher temperatures are used with the forced-circulation systems.

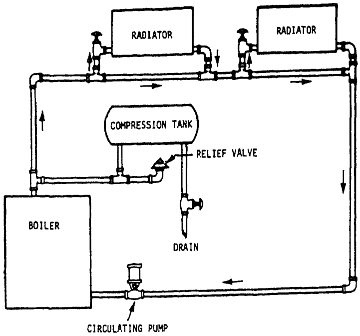
FORCED-CIRCULATION HOT-WATER DISTRIBUTION SYSTEM

Forced-circulation hot-water distribution systems have several advantages. They permit the use of smaller pipe sizes and allow the installation of radiators at the same level as the boiler, or below, without impairing water circulation. By using a circulation pump, a positive flow of water is assured throughout the system. In larger installations, especially where more than one building is served, forced circulation is almost invariably used. With the development of a circulation pump of moderate cost, the forced-circulation system is being used more in small heating installations.

Even as in gravity systems, forced-circulation systems can consist of a one-pipe or a two-pipe, upfeed or downfeed, and can be equipped with a direct or a reversed return. Although these systems usually have closed expansion tanks, they may have open tanks.

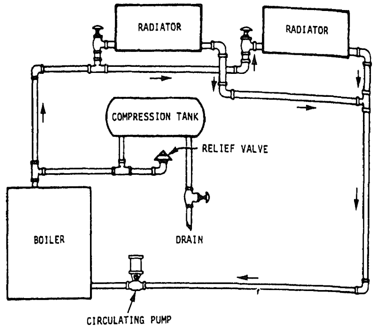
One-Pipe, Closed-Tank, Forced-Circulation System

The general arrangement of a one-pipe, closed-tank, forced-circulation system shown in



54.530.3

Figure 10-9.—A one-pipe, closed-tank distribution system with a circulating pump.



54.530.4

Figure 10-10.—A two-pipe, closed-tank, forced-circulation system.

figure 10-9 is similar to the one-pipe gravity system, but with the addition of a circulating pump.

The circulation to individual radiators is improved by special supply and return connecting tees. These tees, by an ejecting action on the distribution supply main and an ejecting action on the return, combine to use a portion of the velocity head in the main to increase circulation through the radiators. Tees of this type also aid stratification of hot and cold water within the distributing main. They are designed to take off the hot-test water from the top of the main and to deposit the colder water on the bottom of the main.

Two-Pipe, Closed-Tank, Forced-Circulation System

The general arrangement of the piping and radiators for the two-pipe, forced-circulation distribution system is the same as that for the two-pipe gravity system. The relative locations of the compression tank relief valve and the circulating pump are shown in figure 10-10.

DISTRIBUTION SYSTEM COMPONENTS

The component parts of a hot-water distribution system include the following: pipelines, radiators, convectors, unit heaters, circulating pumps, reducing valves, flow-control valves, and special flow fittings.

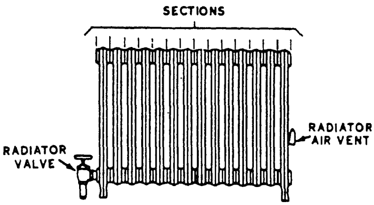
Pipelines

The piping system constitutes the closed passageway for the delivery of hot water to the points where it is used. Pipelines are made of lengths of pipe fastened by screwed, flanged, or welded joints. They have valves and fittings, such as tees, unions, and elbows, according to the needs of the installation. Pipelines are supported by hangers and fastened by anchors. Expansion joints or loops allow for expansion.

Mains and branches of the pipeline should be pitched so the air in the system can be discharged through open expansion tanks, radiators, and relief valves. The pitch is generally not less than 1 inch for every 10 feet. The piping arrangements for a new system should provide for draining the entire system.

Radiators

The radiator transfers heat from the hot water in the pipes of a hot-water heating system into the surrounding air in a room. A radiator is usually constructed of cast iron and assembled in sections, as shown in figure 10-11. Damaged radiator sections can be replaced without replacing the entire radiator assembly.



54.531
Figure 10-11.—A typical cast-iron sectional radiator.

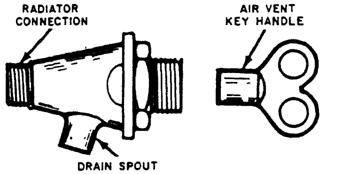


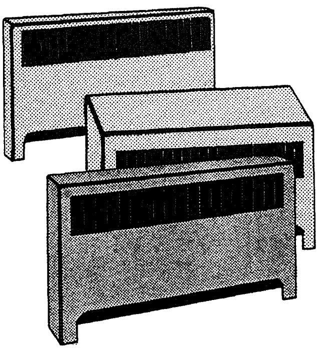
Figure 10-13.—A manually operated key-type air vent.

Radiators usually rest on the floor. However, they can be either mounted on a wall or hung from the ceiling. The location of a radiator depends on the type of room to be heated and its location with respect to the location of the boiler. For instance, in a forced-circulation hot-water distribution system, the radiators may be on the same level with the boiler.

Convectors

Convectors are supported on the wall much in the same way as a pipe.

The convectors consist of a finned tube or pipe mounted in a metal cabinet and transfer heat much in the same way, although a damaged section must be welded or the entire convector must be replaced. (See fig. 10-12.)



54.532
Figure 10-12.—Convectors.

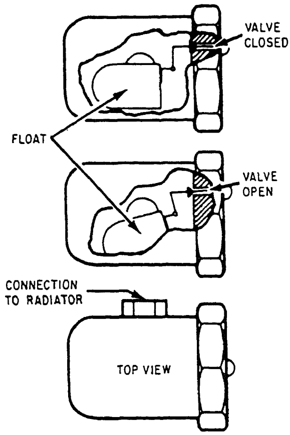


Figure 10-14.—One type of automatic air vent.

Hot-water heating system radiators and high points in the distribution lines must have some type of vent that releases air from the system. Air trapped in the system prevents the circulation of water. For this purpose, a manually operated key-type air vent, like that shown in figure 10-13, can be used.

Manually operated key-type air vents can be replaced by automatic air vents. One type of automatic air vent is shown in figure 10-14. It automatically allows the air that forms in the system to escape. When air vents fail, replace them.

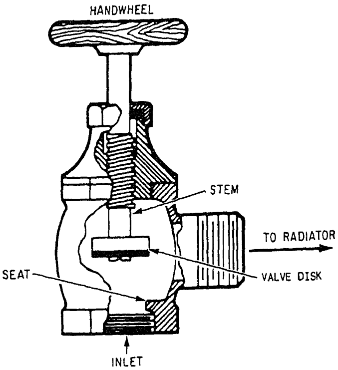


Figure 10-15.—A typical radiator shutoff valve.

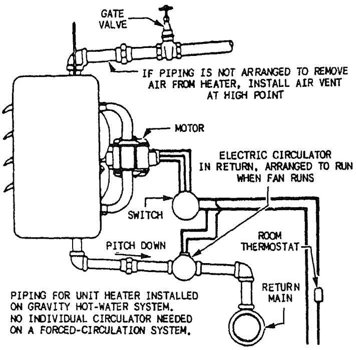


Figure 10-16.—A typical unit heater installation.

Radiators also have shutoff valves, such as the one shown in figure 10-15, which reduce or stop the flow of hot water through a radiator. They are installed in the piping next to the inlet side of the radiator. Occasionally, you must tighten the packing nut on these valves to prevent the water from leaking around the valve stem.

Unit Heaters

A unit heater is used to heat a localized area. The heater consists of a heating coil supplied with hot water. The coil is usually of the finned type, and air is circulated over it by an electric fan. A unit heater installed in a distribution main is shown in figure 10-16.

Servicing unit heaters includes a monthly inspection. Each month, check for water leaks, cleanliness of the finned coils, and the operation of the fan motor. Other accessories which you also should inspect are traps, air vents, fan blades, and valves. Make any needed repairs. Lubricate the electric fan monthly.

Circulating Pumps

A forced hot-water heating system has a water-circulating pump in the return line near the boiler. This pump ensures the positive flow of water regardless of the height of the system or the drop in the water temperature. Greater velocities of water flow are obtainable with forced circulation than with gravity circulation.

Circulating pumps are free of valves and float control elements. They are operated under a sufficiently high water inlet temperature to eliminate the difficulties caused by vapor binding. The pumps are usually operated by electric motors.

During maintenance servicing, check the pump carefully for proper rotation, and lubricate the electric motor and pump according to the manufacturer's instructions. Also, periodically clean the pump of sand, rust, and other foreign matter that has collected in the pump casing. Be sure the pump rotates freely and the shaft packing glands, if there are any, are not drawn up so tight that they score the shaft.

Reducing Valves

A reducing valve is normally installed in the cold-water line going to the boiler. It automatically keeps the closed system supplied with water at a predetermined safe system pressure. These valves are usually set at the factory, but you may adjust them in the shop to a desired pressure. You should install this valve at approximately the same level as the top of the boiler.

Flow-Control Valves

Forced hot-water circulating systems use the flow-control valve shown in figure 10-17. It is

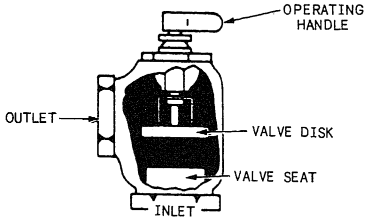


Figure 10-17.—One type of flow-control valve.

normally installed in the distribution main. This valve prevents gravitational flow of water through the system. The valve does not offer any serious resistance to the flow of water when the circulating pump is in operation. However, when the pump is not operating, the small gravitational head of water cannot open the valve. Each week you should check the flow-control valve for proper operational down-free movement. Examine the valve for water leaks and repair it when necessary.

Special Flow Fittings

Various types of special tees designed to deflect main-line water into the radiator branches are used in one-pipe and two-pipe forced-circulation systems. These fittings are designed and calibrated to the size of the radiator and system-operating temperature. Fittings of this type are required with one-pipe, forced-flow systems, and they do equally well for radiators above and below the distribution mains.

MAINTAINING AND TROUBLESHOOTING HOT-WATER HEATING SYSTEMS

Hot-water heating systems require little maintenance other than periodic checks to make certain that all air is out of the system and all radiators are full of water. The circulating pumps should be oiled regularly according to the manufacturer's instructions, and the pressure-relief valves should be checked periodically.

Some of the common discrepancies encountered when troubleshooting hot-water heating systems are as follows:

Boiler Trouble

Symptoms	Remedy
Boiler smokes through the feed doors.	Clean the boiler flues and the flue pipes. Repair any chimney leaks.
Boiler heats slowly.	Increase the draft. Check on the type of fuel. Clean the boiler of scale. Blow down the boiler.
Boiler produces insufficient heat.	Clean the boiler of scale. Change to a larger boiler. Blow down the boiler. Increase the draft, and check on the type of fuel.

Radiator and Unit Heater Trouble

Symptoms	Remedy
Radiators do not heat.	Insufficient water in the system. Bleed the air from the system. Open the radiator valves. Clean the corroded valves, and check the operation of the circulation pump.

Distribution Piping Trouble

Symptoms	Remedy
Distribution piping does not transfer hot water to the radiators.	Insufficient water in the system. Bleed the air from the high points in the distribution piping. Check the operation of the circulation pump. Check for corrosion stoppage in the distribution piping.

● Operator maintenance on the electrically driven feed pump consists mostly of cleaning the pump and motor. However, the pump motor is lubricated according to the manufacturer's specifications. Remember that not using enough lubricant can result in the bearings running dry or seizing on the motor shaft. But, too much lubricant causes the motor to become dirty, and it can result in the motor windings becoming saturated with oil and burning out.

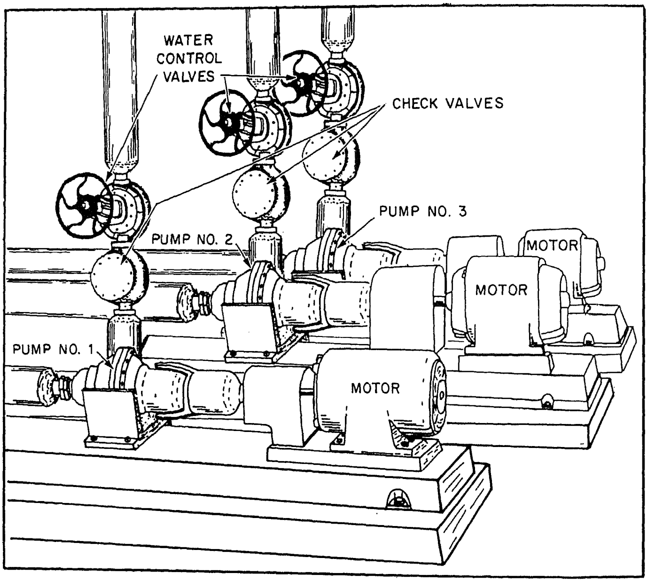
● When a water leak develops around the pump shaft, tighten the packing-gland nuts or repack the stuffing box as necessary. The strainer, installed between the pump and the condensate receiver, should be kept clean to avoid any restriction of the flow of water to the pump.

● The maintenance of feedwater heaters and economizers normally includes removing solid matter that accumulates in the unit; stopping steam and water leaks; and repairing inoperative traps, floats, valves, pumps, and other such associated equipment.

HIGH-TEMPERATURE HOT-WATER SYSTEMS

High-temperature hot-water (HTHW) systems operate at high pressure to maintain water temperature that exceeds the normal boiling temperature of 212 °F (at atmospheric pressure) used in other types of heating systems.

High-temperature hot-water systems consist of standard and heavy-duty equipment, including boilers (sometimes referred to as generators), expansion drums, system circulator pumps, distribution piping, and heat-consuming equipment.



54.534

Figure 10-18.—Typical high-temperature hot-water circulation pumps.

High-temperature hot-water systems have the hot water pumped from the generator throughout the distribution system. The circulator pumps are large enough to deliver the water at sufficient pressure to overcome any drop in the distribution system and the heat-consuming equipment. The major advantages of the HTHW heating system are makeup requirements, minimum maintenance, high thermal efficiency, and safe, easy operation and control.

The HTHW system is a closed system, so the only water waste is the normal leakage at the pump and valve packing glands. Consequently, little water is consumed during system operation. This means only a small amount of makeup water is used, practically eliminating boiler blowdowns. The closed recirculating system operates at high thermal efficiency. All of the heat not used by heat-consuming devices in the system or lost through pipe radiation is returned to the boiler plant. Because few boiler blowdowns are required, the heat loss from blowdowns is kept to a minimum.

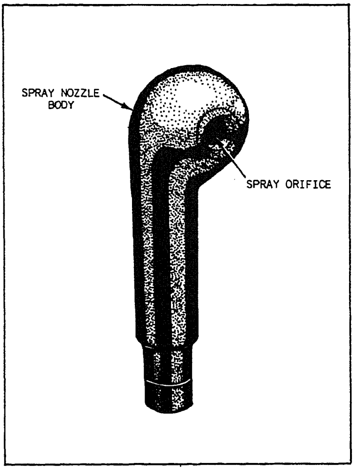
TYPES OF HTHW SYSTEMS

The high-temperature range for most military and federal heating plants is 350 °F to 450 °F which corresponds to saturated pressures of 135 psi to 425 psi. However, some types of plants operate at higher pressures and therefore have higher water temperatures. The installation of HTHW plants that operate at temperatures above 400 °F must be approved by the Naval Facilities Engineering Command. Costs usually determine the maximum water temperature used, because the types of HTHW systems using the higher pressures require more expensive piping, valves, fittings, and heat exchangers.

The degree of complexity of HTHW systems varies according to the size, type, and heat load requirement of the installation. Since methods used to maintain pressure and to assure uniform flow rates depend upon the amount of heat load, they affect the complexity of the heating system. There are two methods of circulating the HTHW through the system: the one-pump system and the two-pump system.

The one-pump system uses only one pump to circulate the hot water throughout the system, which includes the generator. The two-pump system uses one pump to circulate the water through the distribution system, and a second pump to circulate the water through the generator for positive circulation. Figure 10-18 shows some typical pumps that are used for circulation in the HTHW system. Note that the pumps are of the centrifugal type. Each pump shown is used to circulate the water to different areas in the distribution systems.

There are two common ways of heating the water in the HTHW system: one way is to use hot-water boilers or generators and the other way is to use the cascade or direct contact heater. The water in the HTHW generator is heated as low-temperature hot water is heated. In the cascade heater, however, the water is forced through spray nozzles and comes into direct contact with the steam. The steam condenses into the circulating water. A typical spray nozzle head is shown in figure 10-19. The spray nozzles are installed in a combination cascade heater expansion drum. A typical cascade heater



54.535

Figure 10-19.—A typical cascade heater spray nozzle head.

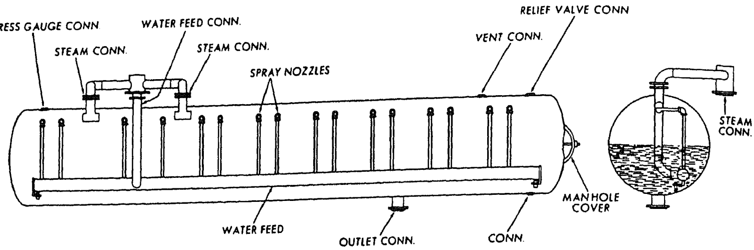


Figure 10-20.—A combination cascade heater expansion drum installation.

expansion drum installation is shown in figure 10-20. In the paragraphs that follow, some ways of pressurizing the HTHW system are discussed.

PRESSURIZING THE HTHW SYSTEM

Since water volume varies with changes in temperature, the extra water must be taken care of when the water is heated. It is desirable to operate with the water above the boiling temperature of 212 °F; therefore, the pressure in the system must be maintained equal to, or greater than, the corresponding saturation (steam or vaporization) temperature. An expansion tank is required because the water, which is not compressible to a smaller volume, expands when it is heated. Also, the pressurization prevents the formation of saturated steam or vaporization when the water temperature is raised. There are two basic designs used for pressurizing HTHW systems: first, the saturated-steam cushion, and second, the mechanical-gas cushion. Although both designs have a variety of modifications, their characteristics are still typical of the basic pressurized system design.

Saturated-Steam Cushion

Pressurizing the heating system with steam in the expansion tank is a natural method. Firing the HTHW generator to maintain the system pressure corresponding to the required saturation (steam or vaporization) temperature pressurizes the system. Excess heat is generated to offset the radiant heat loss from the expansion tank. All of the HTHW in the steam-pressurized system flows through the expansion tank and thereby maintains the saturation (steam or vaporization) temperature there.

The steam in the space in the expansion tank provides the pressure or cushion for the system. The pressure maintained is that of the saturated steam. The water in the lower portion of the tank will be approximately saturation (steam or vaporization) temperature corresponding to this pressure. The water to be used in the HTHW heating system is drawn from the lower part of the expansion tank, mixed with the system return water, and circulated throughout the system. The mixing is necessary to prevent cavitation (steam flashing) at the pump suction.

Here are some conditions that are typical of the saturated-steam cushion design. The expansion tank, either integral or separate, is a part of the HTHW system. The entire amount of hot water flowing in the heating system passes through the expansion tank and exposes the tank to maximum system heat and any form of contamination which, in turn, subjects the expansion tank to thermal stresses and corrosion. There are explosion hazards typical of a steam boiler in the system, and good water-level control is important in maintaining proper operating conditions. Load variations causing supply pressure changes create flashing of saturated liquid in the system and produce water hammer.

Mechanical-Gas Cushion

The expansion tank contains the mechanical-gas cushion and is connected to the HTHW system return line just ahead of the circulating pump suction connection. The tank contains an inert gas (usually nitrogen) and is the source of pressure in this method. When the system has been pressurized by the nitrogen, pressure in excess of saturation must be maintained; that is, the water

temperature throughout the system must always be less than its saturation temperature. In the nitrogen-pressurized system, the expansion tank is installed in the system as a standpipe arrangement so the water does not flow through it. The water in the lower part of this tank is stagnant, except for the changes caused by expansion and contraction brought on by load fluctuations. If you assume the water is virtually incompressible, the tank provides the space available for these changes in the water volume of the system.

Here are some characteristics that are typical of this design. The expansion tank is independent of the generator and remains cool. Corrosion is practically eliminated because the heating system is flooded with the exception of the nitrogen space in the expansion (cushion) tank. When properly designed, the system is sealed with its fixed charge of water and nitrogen. However, this design does not contain a steam drum or any steam spaces that permit the accumulation of steam. The generator tubes are the weakest link in this entire system. An explosion caused by the disssociation of hydrogen and oxygen cannot occur. The formation of steam cools the otherwise red-hot metal surfaces. Hot-water conditions do not allow the flashing of steam.

Operation

To ensure normal operation, fill the system with treated water taken from the water softener. To prevent oxygen corrosion, add the chemicals for treating the water to furnish 20 to 40 parts of sodium sulfite per million parts (ppm) of water. You thereby maintain a pH value of 9.3 to 9.9. While the water is circulating in the generator and in the system, you should fire the boiler at about 25 percent of its rated capacity to bring the system up to normal operating temperature. You should allow the expansion drum vent in steam-pressurized systems to blow for about 1 hour to rid the system of all oxygen and other non-condensable gases.

The start-up and firing of HTHW boilers or generators are done in much the same manner as for domestic hot-water and steam boilers, depending upon the type of fuel-burning equipment used. The specific start-up and operating procedures vary with different installations. Therefore, this information is furnished by your local supervisor and the manufacturer of the equipment.

Coal, oil, and gas are the types of fuels normally used to fire the boilers of HTHW systems. The specific type of fuel used depends upon the type of firing equipment installed in the plant. Each type of fuel requires designated inspections be made and certain precautions be taken to eliminate fire and safety hazards.

When you are transferring fuel oil from one tank to another, be sure both tanks are grounded. Checks must then be made to ensure excessive oil pressures are not generated in the tanks by the expansion of the fuel. Although natural gas is not normally stored on a base ashore, liquid petroleum (LP) gas is often stored near the heating plant. You should check the areas where this gas is stored often to ensure there is no leakage. Liquid petroleum gas is heavier than air, settles in low areas, and creates explosive hazards. When checking for gas leaks, use a standard soap solution.

Because of the large heat storage capacity of HTHW systems, the load demand change for the boiler is slow and smooth. This characteristic provides for improved and safer operation than that provided by the saturated-steam cushion. This brings us to the discussion about the safety characteristics of HTHW.

SAFETY CHARACTERISTICS OF STEAM AND HOT WATER

One of the significant advantages of HTHW is its relative safety, especially at the point of use. The many installations of steam and hot-water heating systems are so familiar to us that we do not normally concern ourselves with their hazards. The high-energy content of HTHW has led to the common belief that it is less safe than other heating media. In case of a break, however, this energy is used in the change of state process and is not available to create a serious hazard. Consequently, the reverse is the case. To describe what happens, the paragraphs that follow compare the effects upon the occurrence of a break or similar mechanical failure in each of four types of heating media commonly used.

LOW-PRESSURE STEAM

A break in a low-pressure steam line results in the forcible ejection of steam, as long as the pressure persists, at a temperature slightly below that of the steam in the pipe. Steam at 5 psi and 230°F discharges to the atmosphere at the temperature of approximately 229°F and at a velocity of about 1,500 feet per second. This is

a definite hazard because the steam rapidly envelops the enclosure at the ejection velocity, and its temperature is high enough to cause considerable bodily harm to persons in this area.

HIGH-PRESSURE STEAM

The action of a break in a high-pressure steam line is similar to that described above for a low-pressure steam line. Because of the greater expansion that takes place, there is a slightly greater drop in temperature with high-pressure steam. For example, steam at 125 psi and 300 °F temperature is discharged into the atmosphere at 290 °F and a velocity of approximately 1,600 feet per second. The energy in the steam is converted into work (kinetic energy) as it flows out of the system. Again, this is a highly hazardous condition.

LOW-PRESSURE HOT WATER

When a failure occurs in a low-pressure hot-water system, scalding water is emitted for a short time until the system pressure reduces to atmospheric pressure. Since the temperature of the water is not above its boiling point at atmospheric pressure, flashing to steam does not occur. Water at 15 psi and 200 °F temperature discharges through a break at atmospheric pressure at a temperature of about 200 °F and at a velocity of about 175 feet per second. Less danger is present than with steam, because the lower water ejection velocity does not tend to fill the enclosure. The condition, however, is still hazardous, especially in the case of overhead piping, because water at 200 °F can produce permanent injuries.

PRESSURIZED HTHW

When a break occurs in an HTHW line, a mixture of water and steam is discharged to the atmosphere. Since the temperature of the water is well above its vaporization point at atmospheric pressure, the energy in the water is used to convert a part of the water from a liquid state into a vapor state. This energy is used in the change of state, and it is not available to do work (kinetic energy). Because the quantity of heat available is sufficient to vaporize only from 20 to 25 percent of the HTHW present, there is no energy available to produce an explosion. Because of the pressure in the system, the mixture of steam and water is ejected initially at a high velocity. Since the pressure is maintained independently by a fixed quantity of nitrogen in the compression tank, the pressure falls rapidly and the velocity of ejection drops to a low value in a short time.

When 25 percent of the water vaporizes, it obtains its heat energy from the other 75 percent of the water. Therefore, the heat content of 75 percent of the water is reduced by the amount of heat that is used to vaporize the 25 percent. The resulting emission temperature of HTHW at 400 °F drops to between 120 °F and 130 °F.

BOILER VERSUS GENERATOR FAILURE

The explosion of a steam boiler can result from excessive steam pressure created inside the steam drum. When this happens, considerable damage is sustained by the heating plant. Severe steam boiler explosions, however, can also occur from the dissociation of hydrogen and oxygen in the tubes or drums. Dissociation takes place whenever water comes into contact with a red-hot metal surface, such as would happen in a boiler, if the water level were allowed to drop too low and then be suddenly raised. If substantial amounts of hydrogen and oxygen accumulate in the steam drum, they will blow the boiler and perhaps the building apart.

Forced-circulation HTHW generators consist only of tubes and headers, and they have no pressure vessels, such as a steam or "mud" drum. The tubes (convectors) in the convection section of the furnace portion of the generator are the weakest link in the system circuits. The thin gauge metal of the tubes collapses from overheating when liquid contact is lost on the interior of the tubes for as short a time as 2 minutes. It is, therefore, not possible to develop high steam pressures within the system because the tube failure occurs in such a short time. The release of water and the consequent drop in pressure to atmospheric pressure upon the collapse of a generator tube prevent the formation of an explosive condition.

INSTALLING THE PIPING SYSTEM

All piping in an HTHW system should be welded. No screwed joints should be permitted, and flanges should be allowed only where necessary, such as at expansion joints, pumps, and generator connections. Only schedule 40 black

steel piping or better is used for HTHW systems. Upon completion, the entire heating system is subjected to a test of 450 psi that lasts for not less than 24 hours.

The possibilities of line failure are remote when the construction recommended above is used. The system piping material is subjected to a minimum factory test of 700 psi. The generator tubes are subjected to an ASME test of 900 psi. All valves and accessories are rated at working pressures of 540 to 1,075 psi at 400°F. The weakest link in the piping network lies within the generator tubing. The worst likely failure is the loss of tubes, and therefore the generator. The safety of the piping system is maintained over the life of the installation because of the absence of corrosion in the hot-water heating systems due to boiler water treatment.

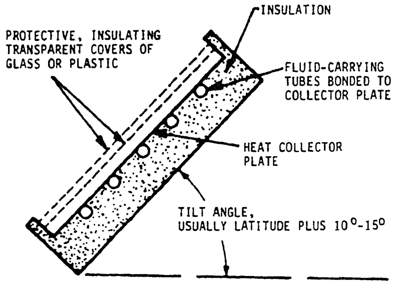


Figure 10-21.—Schematic cross section of a typical solar heat collector with heavy back insulation and two cover sheets.

SOLAR RADIATION SYSTEMS

Energy from the sun is received by the earth as electromagnetic radiation. Most of the energy is received in visible and infrared portions and a small amount as ultraviolet radiation. Energy is beamed to us from approximately 90 million miles. The trip takes just over 8 minutes. It is said if 100 percent of the solar constant were to be collected on an area the size of the United States, we could absorb enough energy in 32 minutes to supply the energy needs of the entire world for a year. The amount of solar energy per unit area per unit time that strikes the surface of the earth is called solar insolation. If measurements were made of the solar energy available in outer space, a fixed amount could be determined. This fixed amount of energy is called the solar constant. This solar constant is as follows: 428 Btu/hr-ft^2 or 2,453 watts/m^2 to 1,940 Langleys/min. Langleys (L) is the most common measurement used. At most, 70 to 80 percent of this amount strikes the surface of the earth; the remainder is absorbed or reflected by the atmosphere. Those solar rays that hit the earth on a clear day are, for the most part, parallel to each other. When there is haze, cloud cover, smog, or dust in the air, the parallel pattern is broken and the rays are deflected in many different directions by these particles of water or dust in the atmosphere. This is why light and heat appear to come at us from all directions.

This is called "diffuse" radiation. With the right solar collector, this "diffuse" radiation can be useful. Because of the filtering effect, only about 1,400 Btu per square foot per day is the average solar intensity on the ground. This is equal in a square mile to the productivity of a large hydroelectric power plant.

COLLECTING SOLAR ENERGY

Collection of solar energy is based on the high absorption of radiant energy by dull, black surfaces and on the "greenhouse effect." The latter refers to the ability of glass to transmit visible radiation but to prevent the loss of heat from the collector plate that radiates at longer wavelengths (infrared frequencies). Glass (or plastic) cover plates are generally used over flat absorber plates to reduce heat loss. (See fig. 10-21.) The heated absorber plate may have a fluid (water, air, or other) pass over it or through tubes attached to the plate. The fluid thus heated may be used to heat potable water, heat spaces, or drive an absorption air-conditioner.

The amount of solar energy collected by a solar collector depends on its efficiency, which is determined by how it is constructed, its configuration, and the choice of materials used.

SOLAR COLLECTOR ORIENTATION

Even though solar collectors can collect heat from the diffuse component of solar radiation, solar systems are designed to use the direct component. Direct radiation is in the form of parallel rays coming straight from the sun. To capture this energy, tilt the solar collector, as

Air	
Advantages	**Disadvantages**
Moderate cost. No freezing problems. Minor leaks of little consequence. As air is used directly to heat the house, no temperature losses due to heat exchangers (devices which transfer heat from one fluid to another), when the system is used for space heat. No boiling or pressure problems.	Can only be used to heat homes; cannot presently be economically adapted to cooling. Large air ducts needed. Larger storage space needed for rocks. Heat exchangers needed if system is to be used to heat water.

Water or Liquid	
Advantages	**Disadvantages**
Holds and transfers heat well. Water can be used as storage. Can be used to both heat and cool homes. Compact storage and small conduits.	Leaking, freezing, and corrosion can be problems. Corrosion inhibitors needed with water when using steel or aluminum. There are liquids which are noncorrosive and nonelectrolytic; however, they are toxic and some of them are flammable. A separate collector loop using a nonfreezing fluid and a heat exchanger or, alternatively, a draining water or inhibited water system are required to prevent freezing. In warm regions, where freezing is infrequent, electric warmers or recirculation can be used.

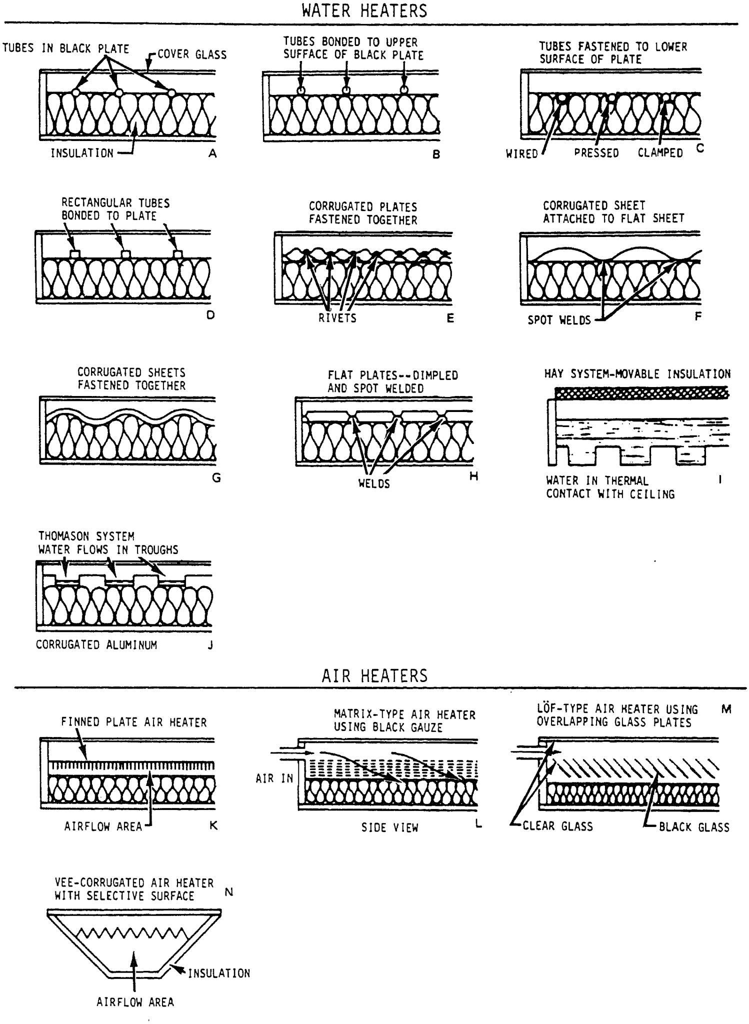
shown in figure 10-21, so it is nearly perpendicular to the solar rays.

In addition to choosing the best collector tilt angle, consideration must be given to the orientation of the collector; that is, the direction the collector faces. Normally, true south is the best and most frequent choice. However, slightly west of south (10 degrees) may be preferable in some locations if early morning haze or fog is a regular occurrence.

Equally important as collector location is keeping the collectors out of the shade, especially between 0900 and 1500 hours, when most of the useful energy collection occurs. In summary, although many buildings do not have a "perfect" solar orientation, there are still many places with good solar energy potential.

COLLECTORS

The collector is the most important and one of the most expensive parts of a solar-heating system. Collectors for space and water heating are of two basic types: liquid and air. Liquids may be water, an antifreeze mixture, or various hydrocarbon and silicone heat transfer oils. Air types of collectors use air as the collector medium. For the advantages and disadvantages of air and liquid heating systems, see table 10-1. The absorber plate is that part of the collector which absorbs the solar energy and converts it to thermal energy. A portion of the thermal energy is carried to the building or thermal storage unit by the medium that circulates through passages in the absorber plate. The absorber plates can be made of metal, plastic, or rubber compounds. The metals commonly used in order of decreasing thermal conductivity are copper, aluminum, and steel. Plastic (polyolefin) and rubber (ethylene propylene compound) are relatively inexpensive. However, because of their low thermal conductivity and their temperature limitations, they are suitable only for low-temperature applications, such as heating water in swimming pools or for use with water source heat pumps. Typical cross sections of solar collector types are shown in figure 10-22.



54.536

Figure 10-22.—Types of solar heat collectors.

Flat-plate collectors are most suitable for low-temperature applications, such as domestic hot-water and space heating. They collect both direct and diffuse radiation. It is not required that they track the sun. Tubes should be one-half inch in diameter or greater for low-pressure drop and longer life. The better the attachment of tube-to-plate (such as by soldering), the better the heat transfer.

Liquid and air collectors each have some advantages. Liquid types are most suited to domestic hot water. The collector area is usually smaller.

The design procedures for air collectors differ however. Heat transfer oils used in liquid systems offer freeze protection and some corrosion protection, but they also require heat exchangers for heating domestic hot water, as do antifreeze-water mixtures.

SELECTIVE SURFACES

Some collectors are manufactured with a black coating that absorbs the high-frequency incoming solar radiation well and emits low-frequency infrared radiation poorly.

COLLECTOR COVERS (GLAZES)

The transparent covers serve to admit solar radiation to the absorber while reducing convection and radiation heat losses from the collector. The covers also protect the absorber from dirt, rain, and other environmental contaminants.

The materials used for covers include glass or plastic sheets. Glass is most commonly used because of its superior optical properties and durability. Standard plate glass reflects about 8 percent and absorbs about 6 percent of normal incident solar radiation, resulting in a transmissivity of about 86 percent. Glass is subject to impact damage and is more expensive than plastic; however, it does not degrade in sunlight or at high collector temperatures and is generally considered to be more durable than plastic.

Although resistant to impact damage, plastics generally degrade in sunlight and are limited as to the temperatures they can sustain without undergoing serious deformation. In general, acrylic is the most ultraviolet-resistant, and polycarbonate offers good impact and high-temperature properties.

COLLECTOR GASKETS AND SEALANTS

Gaskets and sealants must be carefully selected if a collector is to have a long life. Generally, the housing and the glazing have different rates of thermal expansion. Gaskets and sealants form a flexible interface between the two components and seal out moisture and other contaminants. If they fail, moisture will fog the glazing and may damage the absorber coating and the insulation. These problems can drastically reduce the thermal performance of the collector.

Two suitable sealing methods are shown in figure 10-23. The gaskets provide flexible support and the primary weather sealant ensures against moisture leakage. Dessicants are sometimes placed between the two glazings to absorb any moisture that may remain after cover installation.

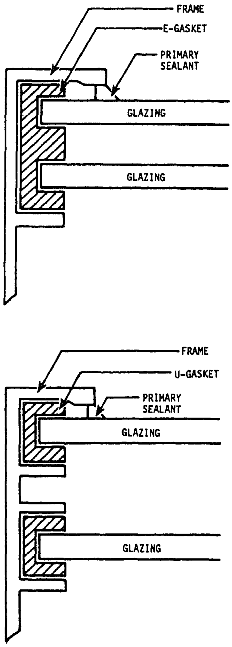


Figure 10-23.—Typical sealing method for single or double glazing.

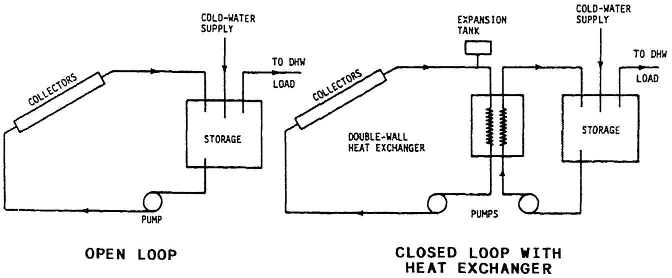


Figure 10-24.—Typical configuration for solar water-heating systems.

When you are selecting collector gaskets and sealants, certain material requirements must be kept in mind. The gaskets and seals must do the following:

1. Withstand significant expansion and contraction without destruction
2. Adhere effectively to all surfaces
3. Resist ultraviolet degradation
4. Resist outdoor weathering
5. Not harden or become brittle
6. Withstand temperature cycling from −30 °F to 400 °F

Both EPDM and silicone rubbers have been found adequate for use as gasket material. Silicone sealants have exceptional weathering resistance and have received widespread use for many years.

COLLECTOR FLUID—CORROSION AND FREEZE PROTECTION

The choice of collector fluid is important because this is the lifeblood of the system. The cheapest, most readily obtainable, and thermally efficient fluid to use is ordinary water. However, water suffers from two serious drawbacks: it freezes and it can cause corrosion. Therefore, the choice of collector fluid is closely linked to the type of solar system, the choice of components, future maintenance, and several other factors.

Implicit in this discussion is the use of fluid other than air as the collector fluid. As explained in table 10-1, an air solar system does not suffer from corrosion or freezing effect, but its low density and heat capacity require the use of fans and large ducts, large storage volumes, and is generally not suitable for domestic water heating.

If there is no danger of freezing and the collector loop consists of all copper flow passages, then ordinary water would be the choice for collector fluid. If freezing conditions are encountered, there are a number of designs that should be considered before it is decided to use a heat transfer oil or antifreeze mixture. For the purposes of this discussion, these freeze protection schemes are summarized here using figure 10-24 to demonstrate the basic open loop-type collector circuit.

Drain Down Method

The water in the collector is drained into the storage tank when temperatures in the collector approach freezing. This scheme requires automatic valves to dump the water and purge the air from the system. Often a large pump will be required to overcome the system head and reprime the collectors. A way to avoid automatic (solenoid) valves is to drain the collectors whenever the pump shuts off. This still requires a larger pump. Heat exchangers may be required to separate potable water from nonpotable water.

Heat Tapes

Electrical-resistant heat tapes are thermostatically activated to heat the water. This scheme requires extra energy and is not completely reliable. The insertion of heat tapes into preconstructed collectors may be difficult.

Recirculating Method

In this method, the control system shown in figure 10-24, merely turns on the pump if freezing approaches. In this way, warm water from storage circulates through the collectors until the freezing condition is over. The only extra component needed is a freeze sensor on the collector, which is a minimum cost item. However, by circulating heated water, the capacity of storage decreases and less is available the following day.

HEAT TRANSFER FLUID

If the preceding methods are not acceptable or if the choice of water is unacceptable because of concern about corrosion, then a heat transfer fluid must be used. The heat transfer fluid must be used with a heat exchanger in a "closed-loop" configuration.

The type of heat transfer fluids available may be divided into two categories: nonaqueous and aqueous. Silicones and hydrocarbon oils make up the nonaqueous group, while the aqueous heat transfer fluids include untreated potable (tap) water, inhibited distilled water, and inhibited glycol/water mixtures. The potable tap water and inhibited distilled water do not offer freeze protection.

Silicone Fluids

Silicone heat transfer fluids have many favorable properties that make them prime candidates for collector fluids. They do not freeze, boil, or degrade. They do not corrode common metals, including aluminum. They have excellent stability in solar systems stagnating under 400 °F. Silicone fluids are also virtually nontoxic and have high flash and fire points. Current evidence indicates that silicone fluids should last the life of a closed-loop collector system with stagnation temperatures under 350 °F to 400 °F. The flash point is fairly high, 450 °F, but since HUD standards state that heat transfer fluids must not be used in systems whose maximum stagnation temperature is less than 100 °F lower than the flash point of the fluid, this limits most silicone oils to systems with a maximum temperature of 350 °F or less. Also, silicones do not form sludge or scale, so system performance does not decrease with time.

The main drawback of silicone fluids is their cost. The cost of the 20 to 30 gallons of collector fluid required for a typical 500 ft^2 collector system becomes considerable. As with hydrocarbon oils, the lower heat capacity and higher viscosity of silicone fluid require larger diameter and more expensive piping. Because of the higher viscosity, larger pumps will be required and subsequently, higher pumping costs. One other problem with silicone fluids is the seepage of fluid at pipe joints. This problem can be prevented by proper piping installation and by pressurizing the system with air to test for leaks. There have also been reports of seepage past the mechanical seals of circulating pumps.

Silicones have the advantage of lasting the life of the system with little maintenance. The high initial cost of silicone heat transfer fluid may be less than the savings that result from minimum maintenance and no replacement of collector fluid. The use of silicone fluid allows aluminum absorbers to be used without fear of corrosion. Hydrocarbon oils, like silicones, also give a long service life, but cost less. They are relatively noncorrosive, nonvolatile, environmentally safe, and most are nontoxic. They are designed for use in systems with lower operating temperatures, since some brands break down at higher temperature to form sludge and corrosive organic acids.

Distilled Water

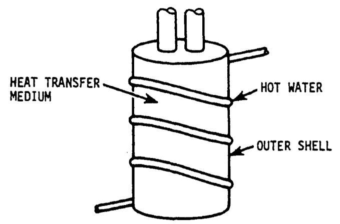
Distilled water has been suggested for use in solar collectors, since it avoids some of the problems of untreated potable water.

However, distilled water is still subject to freezing and boiling. For this reason, an antifreeze/antiboil agent, such as ethylene glycol, is often added.

Water/Antifreeze

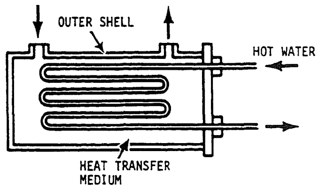
Nonfreezing liquids can also be used to provide freeze protection. These fluids are circulated in a closed loop with a double-wall heat exchanger between the collector loop and the storage tank. (See fig. 10-25.)

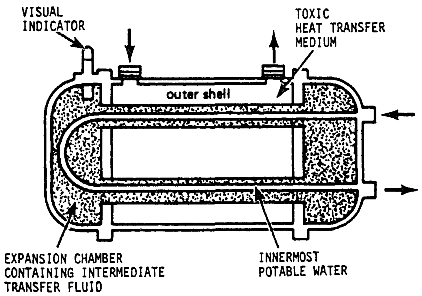
Water/antifreeze solutions are most commonly used. Ethylene and propylene glycol are the two most commonly used antifreezes. A 50-50 water/glycol solution provides freeze protection down to about −30 °F and also raises the boiling point to about 230 °F.



DOUBLE WALL. ANOTHER METHOD OF PROVIDING A DOUBLE SEPARATION BETWEEN THE TRANSFER MEDIUM AND THE POTABLE WATER SUPPLY CONSISTS OF TUBING OR A PLATE COIL WRAPPED AROUND AND BONDED TO A TANK. THE POTABLE WATER IS HEATED AS IT CIRCULATES THROUGH THE COIL OR THROUGH THE TANK. WHEN THIS METHOD IS USED, THE TUBING COIL MUST BE ADEQUATELY INSULATED TO REDUCE HEAT LOSSES.

SHELL AND TUBE. THIS TYPE OF HEAT EXCHANGER IS USED TO TRANSFER HEAT FROM A CIRCULATING TRANSFER MEDIUM TO ANOTHER MEDIUM USED IN STORAGE OR IN DISTRIBUTION. SHELL AND TUBE HEAT EXCHANGERS CONSIST OF AN OUTER CASING OR SHELL SURROUNDING A BUNDLE OF TUBES. THE WATER TO BE HEATED IS NORMALLY CIRCULATED IN THE TUBES, AND THE HOT LIQUID IS CIRCULATED IN THE SHELL. TUBES ARE USUALLY METAL, SUCH AS STEEL, COPPER, OR STAINLESS STEEL. A SINGLE SHELL AND TUBE HEAT EXCHANGER CANNOT BE USED FOR HEAT TRANSFER FROM A TOXIC LIQUID TO POTABLE WATER BECAUSE DOUBLE SEPARATION IS NOT PROVIDED AND THE TOXIC LIQUID MAY ENTER THE POTABLE WATER SUPPLY IN A CASE OF TUBE FAILURE.





SHELL AND DOUBLE TUBE. THIS TYPE OF HEAT EXCHANGER IS SIMILAR TO THE PREVIOUS ONE EXCEPT THAT A SECONDARY CHAMBER IS LOCATED WITHIN THE SHELL TO SURROUND THE POTABLE WATER TUBE. THE HEATED TOXIC LIQUID THEN CIRCULATES INSIDE THE SHELL BUT AROUND THIS SECOND TUBE. AN INTERMEDIARY NONTOXIC HEAT TRANSFER LIQUID IS THEN LOCATED BETWEEN THE TWO TUBE CIRCUITS. AS THE TOXIC HEAT TRANSFER MEDIUM CIRCULATES THROUGH THE SHELL, THE INTERMEDIARY LIQUID IS HEATED, WHICH, IN TURN, HEATS THE POTABLE WATER SUPPLY CIRCULATING THROUGH THE INNERMOST TUBE. THIS HEAT EXCHANGER CAN BE EQUIPPED WITH A SIGHT GLASS TO DETECT LEAKS BY A CHANGE IN COLOR (TOXIC LIQUID OFTEN CONTAINS A DYE) OR BY A CHANGE IN THE LIQUID LEVEL IN THE INTERMEDIARY CHAMBER, WHICH WOULD INDICATE A FAILURE IN EITHER THE OUTER SHELL OR INTERMEDIARY TUBE LINING.

54.537

Figure 10-25.—Heat exchangers for solar water-heating systems.

OTHER TYPES OF SOLAR COLLECTORS

The three most common types of solar collectors are flat-plate collectors, evacuated tube collectors, and concentrating collectors. Because of certain cost and performance advantages, flat-plate collectors have been used extensively for domestic water heating and space heating. Evacuated tube and concentrating collectors are used mostly in solar applications requiring high temperatures. A brief description follows.

Flat-Plate Collectors

The flat-plate collectors are much simpler than the concentrating collectors. They do not need to face directly at the sun; they can absorb diffused light and almost anyone can make one. We know that dark surfaces absorb radiation, and lighter ones tend to reflect it. A flat-plate collector is basically a black sheet of metal with fluid channels or conduits running over, under, or even through it.

A flat-plate collector works much like a greenhouse. Rays come through the glass, reflect off the walls and the floor of the greenhouse, but can't escape back into the atmosphere. When rays of short wavelength hit the absorber plate, some of their energy is reradiated back toward the source, but their intensity is weakened—thus increasing the length of the waves. Because they can't pass back through the glazing, they hit the absorber again and again, giving the plate several chances to absorb them.

Evacuated Tube Collectors

Figure 10-26 shows an evacuated tube collector. This type of collector uses a vacuum between the absorber and the glass outer tube to reduce convection and conduction heat losses significantly.

Evacuated tube collectors operate essentially the same as flat-plate collectors. Solar radiation passes through the outer glass tube and is absorbed by the coated absorber. Heat energy is transferred to fluid flowing through the absorber.

Most evacuated tube designs collect both direct and diffuse radiation efficiently, but certain types are specifically designed for more efficient collection of direct radiation. Although evacuated tube collectors are considerably more expensive than typical flat-plate collectors, they are much more efficient when high collection temperatures are needed for operating absorption chillers or for industrial processing.

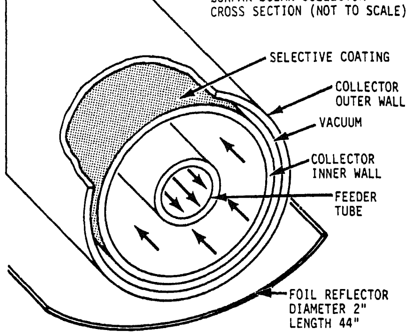


Figure 10-26.—Evacuated tube solar heat collector.

They may not be as efficient as flat-plate collectors at low temperatures, such as domestic water heating and space heating.

Concentrating Collectors

Concentrating, or focusing, collectors intercept direct radiation over a large area and focus it onto a small absorber area. These collectors can provide high temperatures more efficiently than flat-plate collectors, since the absorption surface area is much smaller. However, diffused sky radiation cannot be focused onto the absorber. Most concentrating collectors require mechanical equipment that constantly orients the collectors toward the sun and keeps the absorber at the point of focus.

There are many types of concentrating collectors. The most popular types are the parabolic trough, the linear-trough fresnel lens, and the compound parabolic mirror. Figure 10-27, view (A), shows a linear concentrating or parabolic-trough collector. It collects energy by reflecting direct solar radiation off a large curved mirror and onto a small absorber tube that contains a flowing heat transfer liquid. The absorber tube is encased in a glass or metal tube that may be evacuated. This type of collector must track the sun and can collect only direct radiation.

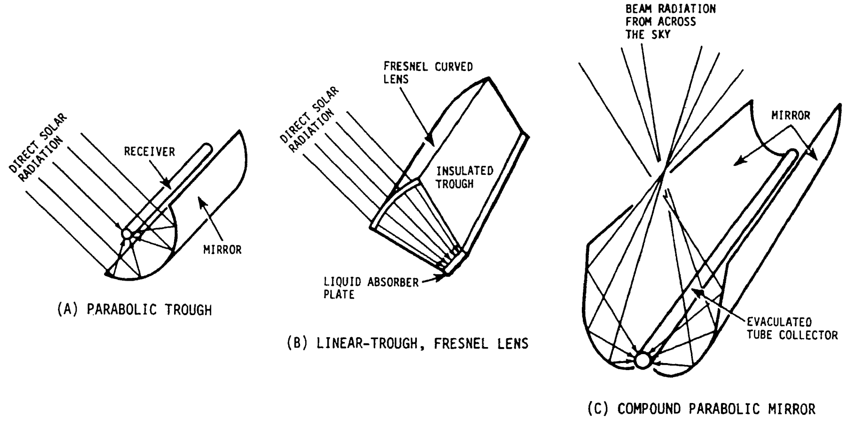


Figure 10-27.—Concentrating collectors for solar energy.

Figure 10-27, view (B), shows a linear-trough, fresnel lens collector. In this design, a curved lens is used to focus incoming rays onto a small absorber plate or tube through which the heat transfer liquid is circulated. This type of collector also requires a tracking mechanism and can collect only direct radiation.

Figure 10-27, view (C), shows a compound parabolic mirror collector. The design of the mirrors allows the collector to collect and focus both direct and diffuse radiation without tracking the sun. Periodic changes in the tilt angle are the only adjustments necessary.

Direct radiation is intercepted by only a portion of the mirror at a time; thus, this collector does not collect as much solar energy as a focusing collector which tracks the sun. It is, however, less expensive to install and maintain. The absorber tube is encased within an evacuated tube to reduce heat losses.

Many other types of concentrating collectors have been developed that produce high temperatures at good efficiencies. However, the high cost of installing and maintaining tracking collectors restricts their use to solar cooling and industrial applications where extremely high fluid temperatures are required. In addition, concentrating collectors must be used only in those locations where clear-sky direct radiation is abundant.

ENERGY STORAGE AND AUXILIARY HEAT

Since effective sunshine occurs only about 5 to 6 hours per day (in temperate latitudes) and since heating and hot-water loads occur up to 24 hours a day, some type of energy storage system is needed when using solar energy.

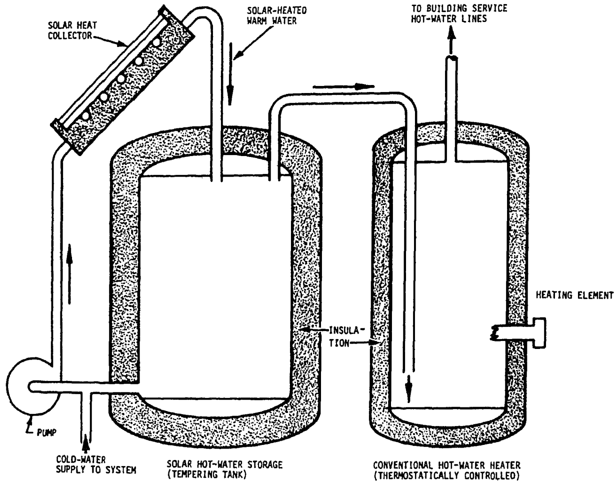
Practical experience in the industry, as well as computer simulations and experiments, has resulted in general rules of thumb for storage sizing. These guidelines give storage sizes for which the performance and cost of active solar systems are optimized and relatively insensitive to changes within the range indicated.

Water Systems

Since water has a specific heat of 1 Btu/lb-°F, then 15 pounds of water storage is needed per square foot of collector or 1.8 gallons of storage is needed for each square foot of collector.

Air Systems

Since rock has a specific heat of 0.21 Btu/lb-°F and rock densities typically contain

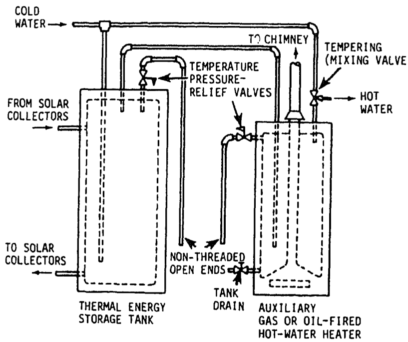


54.539

Figure 10-28.—Schematic of potable hot-water heating systems, using solar storage (tempering) tank ahead of the conventional fueled or electric service water heater.

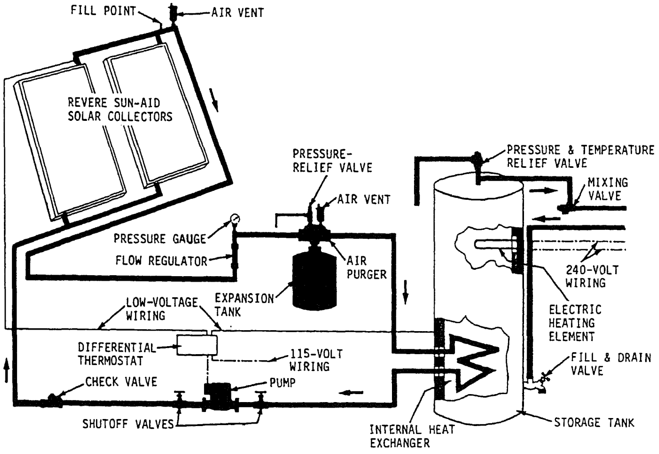
20 to 40 percent voids, then the optimum storage size is 0.8 ft^3 per square foot of collector.

- Storage volumes in this range store the equivalent overnight of one full day of heating. A typical domestic hot-water system is shown in figure 10-28. The use of two tanks ensures that when hot water from the first (tempering) tank is available, the auxiliary heat does not come on; also less total fuel is used to bring the smaller second tank up to temperature. Single-tank arrangements, while possible and economical, are not recommended because they tend to activate the heating element every time there is a draw of water rather than wait for the solar collectors to provide additional heated water. The two-tank arrangement (fig. 10-29) avoids this control problem. Two-tank arrangements are suited to retrofits since the second tank (the water heater) is already there. A variation would be to use a heat exchanger (copper coil) (fig. 10-30) in the tempering tank collector loop for freeze protection. The tempering tank then becomes an inexpensive unpressurized tank.



54.540

Figure 10-29.—Typical DHW installation.



NOTES:

(1) Piping insulation not shown.

(2) Some installations may require the use of nontoxic fluid or double walls between potable water and collector loop. This can be accomplished by the use of propylene glycol, silicone fluids, or the addition of a heat exchanger and pump between the collector loop and storage tank.

54.541

Figure 10-30.—A DHW system with heat exchanger in hot-water storage tanks.

Another method of heat storage in air systems is latent heat storage. Latent heat is stored in a material as it changes phase from a solid to a liquid. Materials that have melting points near the temperatures supplied by solar collectors store heat as they melt and release it as they resolidify. The two materials that have received the most attention are salt hydrates and paraffins.

Storage Tanks

Water may be stored in a variety of containers usually made of steel, concrete, plastic, fiber glass, or other suitable materials.

Steel tanks are commercially available and have been used for water storage. They are available in many sizes and are relatively easy to install. However, steel tanks are susceptible to corrosion and should be lined or galvanized. Dissimilar metal at pipe connections should be separated by high-temperature rubber connections or galvanic corrosion will occur. Steel tanks must be well insulated to minimize heat losses.

Fiber glass and plastic tanks are corrosion-resistant and easily installed. They are available in many shapes and sizes. Although many commonly fabricated tanks begin to soften at temperatures above 140°F, there are more expensive, specially fabricated tanks available that can withstand temperatures up to 150°F. The types of plastics needed to store large quantities of water at high temperatures can be more expensive than steel. Buried tanks must be protected from groundwater and buoyant forces resisted. The tank must be reasonably accessible for repairs. In mild or warm climates, an outdoor location may be feasible.

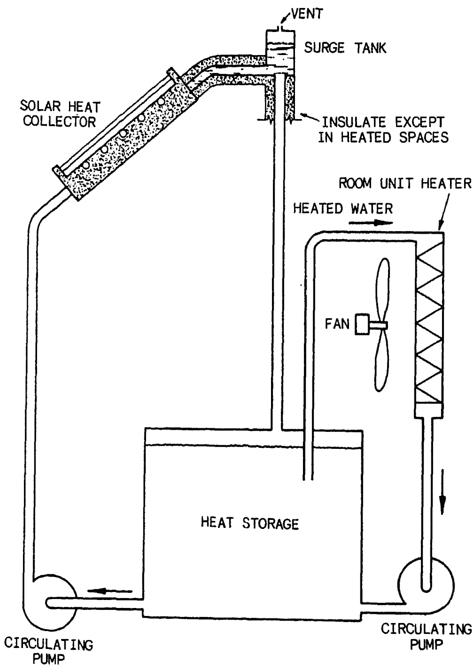
Domestic Hot-Water Systems (DHW)

Domestic hot-water systems (without space heating) may use lined, insulated, or pressurized tanks similar to the conventional water heater. Appropriate temperature- and pressure-relief valves must be used. Since it is possible for solar collectors to reach hot temperatures, a tempering or mixing valve should be used. A typical two-tank installation with proper valves and connections is shown in figure 10-29.

To size the collectors and storage tank, you must estimate or measure the hot-water consumption of the facility or building. For typical family residences, 20 gal/day/person of hot water is normally consumed. If the hot-water consumption is larger than average, use 30 gal/day/person. So, 80 to 120 gal/day should serve a typical four-person family.

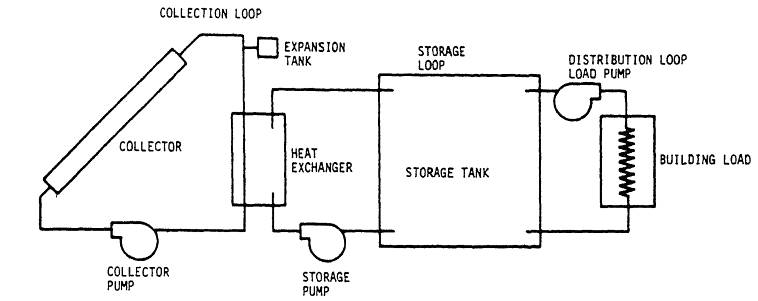
Thermosiphon Systems

A variation of DHW system is the thermosiphon system. It uses the principle of natural convection of fluid between a collector and an elevated storage tank. The advantage is no pump or controller is needed. The bottom of the tank should be mounted about 2 feet higher than the highest point of the collector. This is the main disadvantage because structural requirements often prohibit the weight of a water tank on a high point of the structure. Also, since the thermosiphon system is connected directly to the potable water supply, it cannot be protected from



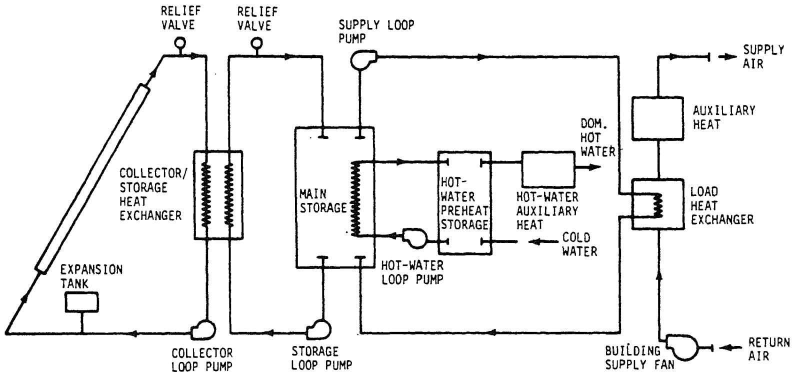
54.542

Figure 10-31.—Minimum heating system showing relationship of collector, storage, and room unit heater.



54.543

Figure 10-32.—Space heating system with closed-loop collector.



54.544

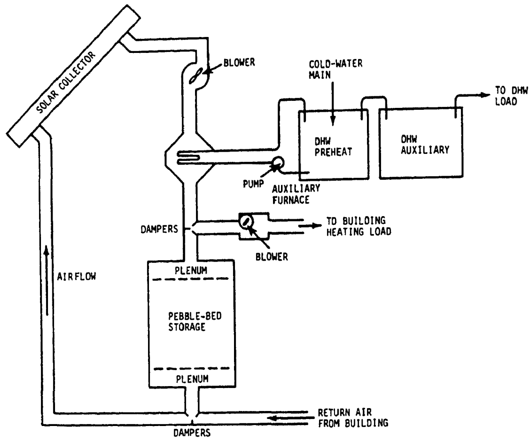
Figure 10-33.—Space heating and domestic hot-water systems.

freezing. A heat exchanger cannot be effectively used in this system.

Space Heating and DHW Systems

Space heating systems are a simple extension of the domestic hot-water (DHW) systems. (See fig. 10-30.) The collectors and storage tank need to be resized to provide greater loads. A heat delivery system is added and the auxiliary heater (or existing heater) is connected into the system as backup. The design of the space heating system, if a retrofit, depends on the existing system. Water-to-air heat exchangers may be placed in existing ductwork, in which case, an unpressurized, unlined tank may be used. This represents a minimum heating system, as shown in figures 10-31 and 10-32.

Domestic hot water could be added to the system shown in figure 10-33 by adding a preheat coil in the storage tank. Figure 10-31 has the potential to provide some cooling to the building



54.545

Figure 10-34.—Typical air types of space heating systems.

by using the collector at night to radiate heat to the sky and store cool water for use during the day. Or a heat pump could be used to cool the building, reject heat to the storage tank during the day, and then, as before, cool the tank at night through the solar collectors. Unglazed collectors are superior to glazed collectors for this application. There are many variations that can be used with the configurations shown.

Air types of space heating systems are receiving increased attention, and a typical system is shown in figure 10-34. (See table 10-1 for advantages of air versus liquid.) The heat storage tank is replaced by a rock bed (nominally 1 to 3 inches in diameter). Rock provides desirable temperature stratification. Designs should emphasize minimum pressure drop through the rock bed. The rocks can be stored in a bin, which should be insulated, or beneath the building if this is feasible. Heat collected by the collectors is blown through the rock bed from top to bottom. Heat is delivered from storage to the building by circulating air in the reverse direction, bottom to top. Note that in contrast to water storage, heat cannot be added to and removed from the rocks at the same time.

During heat collection, the rocks at the top of the bin attain a temperature almost equal to that of the incoming solar-heated air, while the air leaving storage is delivered to the collectors at the minimum temperature of the rocks. The conduction between the rocks is small; thus, with no air circulation, the rock bed remains stratified with the top of the rock bed warmer than the bottom. Also, limited conduction and convection in the rock bed significantly reduce heat loss from the rock bed.

Heat is drawn from storage by circulating air from the building directly through the rock bed from bottom to top. The air is delivered to the building at a temperature near the maximum temperature of the collectors. If additional heat is required, supplementary heat is added downstream from the storage unit. This system allows the rock bed to deliver useful heat until all of the rocks are at room temperature.

A variation is a no-storage air heating system that circulates heated air when available. Performance is limited to daytime heating because of the lack of storage, but such systems are well suited to warehouses and factories with daytime operations.

Domestic hot water is provided by pumping the water in the preheat tank through an air-to-water heat exchanger placed in the return air duct from the collectors. This is not efficient and is one of the disadvantages of the air system.

Heat Distribution for Liquid Types of Solar Systems

The temperature requirements of a hydronic heating system depend on the amount of heat exchanger surface. Most baseboard heaters have comparatively small surface areas, so they require higher temperatures, typically about 180 °F. If larger heat transfer areas are available as in older or modified hot-water systems, temperatures of 120 °F may be sufficient. Temperatures of 100 °F to 120 °F are adequate for the system that uses entire floors, walls, and ceilings as radiator surfaces.

During the winter, typical liquid types of solar systems are seldom operated at delivery temperatures above 150 °F. Thus it is evident that the use of solar-heated water in standard baseboard heaters is impractical. Only modified baseboard heaters of adequate size or radiant panels are suitable for use in hydronic systems that use solar-heated water.

One of the most economical means of auxiliary heat supply and heat distribution for liquid types of solar systems involves the use of a warm-air system. A typical system is shown in figure 10-35. In this system, the warm-air furnace is located downstream from a liquid-to-air heat exchanger which is supplied with solar-heated water. The furnace can then serve to boost air temperature when insufficient heat is available from the solar-heated water, or it can meet the full heat load if no heat is available in solar storage. Auxiliary heat can be supplied by a gas, oil, or electric furnace, or by the condenser of an air-to-air heat pump.

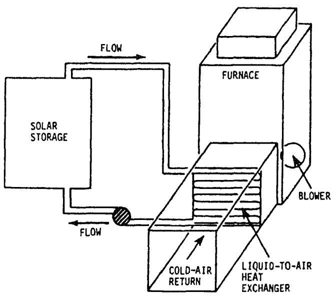


Figure 10-35.—A liquid-to-air heat delivery system.

Another method of heat distribution is to use a water-to-air heat pump that draws heat from the solar storage tank and pumps it to a condenser coil placed in a central air duct. The advantage of this system is that it can effectively use heat from solar storage at temperatures down to 45 °F; thus, more of the stored heat is available. Also, average storage temperatures are lower, resulting in significantly increased collector efficiency. Some manufacturers are combining solar systems with heat pumps to reduce auxiliary energy costs. When a heat pump and solar system are combined in this manner, the system is usually called a solar-assisted or solar-augmented heat pump (SAHP) system.

Solar-assisted heat pump systems can be configured in many different ways. For example, the solar collectors can be either water or air types; the heat storage medium can be water or a solid material, such as rock or brick; and the heat pump can be of either the air-to-air design or the water-to-air design. But heat pumps have a characteristic that can limit their effectiveness: the efficiency and capacity of a heat pump decrease as the temperature of the heat source (usually outdoor air) decreases. This deficiency can be overcome, however, by using solar collectors to gather the energy of the sun to keep the heat source in the temperature range required for efficient heat pump operation.

Heat Distribution for Air Types of Solar Systems

The pipes and pumps of the liquid types of solar systems are replaced by air ducts and fans. The warm-air system is obviously the best heat distribution system for use with an air type of solar system. The ability to circulate air to the building directly through the collectors is one of the major advantages of this system. The rock-bed storage also works best with a warm-air system.

Although warm air as low as 100 °F can be used to heat an occupied building, most existing warm-air systems are sized assuming warm-air temperatures of 120 °F to 150 °F. Typical midday collection temperatures usually range from 130 °F to 170 °F. Maximum storage temperatures are

typically around 140°F at the end of the collection period. Thus, the heating load can be met by the temperature of the solar-heated air a large portion of the day. When storage temperatures are insufficient to maintain the desired temperature of the building, heat from an auxiliary source must be added to supplement the solar-heated air. The auxiliary furnace is located downstream from the rock bed so the rock bed serves as a preheater for the furnace. This arrangement allows the rock bed to deliver useful heat until all of the rocks are at room temperature.

An air handler unit provides the dampers and blowers necessary to direct air circulation between the solar collectors, rock bed, and building. An air handler unit may be more expensive than the combined cost of individual dampers and blowers, but it is probably less expensive to install. It is also more compact.

REFERENCES

Cleaver-Brooks Operation, Service, and Parts Manual, Nos. 750-90 and 750-91, Cleaver-Brooks Division of Aqua-Chem Inc., Milwaukee, Wisc., 1983.

Unit Information Service Manual, Lennox Industries Inc., Dallas, Tex., 1980

CHAPTER 11

GALLEY EQUIPMENT

Learning Objective: Identify the procedures used for maintenance of galley equipment.

Basically, this chapter presents information on ways to maintain common types of galley equipment. Because of the differences in types of equipment you are expected to maintain, only general information is presented in this chapter. Remember, you should study the manufacturer's manual that comes with a new piece of equipment before you attempt to maintain it.

MAINTENANCE OF GALLEY EQUIPMENT

Galley equipment must be maintained in a safe, sanitary, and economical way. Utilitiesmen not only install and maintain the equipment themselves, but they also supervise others who perform this type of work. It is always good practice to post operating instructions near the various pieces of equipment in a galley or a bakeshop. This will help to ensure that operators do not abuse the machines. This is particularly important where messmen and strikers are working. As a further safeguard, you should conduct periodic preventive maintenance inspections, as required for the equipment at your location or as called for in the manufacturer's instructions. After the inspection, you should attach a tag to each piece of equipment that contains pertinent information, such as the date, the type of inspection, and by whom the inspection was made.

The maintenance of food preparation equipment may vary. In peacetime, most types of equipment are located in a permanent galley or bakeshop. While deployed to an island or an overseas shore station, a construction battalion might have either a permanent galley or a semi-permanent galley, using either field units or fixed types of equipment. In a disaster—hurricane, flood, or fire—Seabees may be called upon to help. In such cases, field units—of the same type used in combat zones—are used for preparing food. Whatever the need or the location, your most important duty is to keep all items of equipment in a condition of readiness to ensure safe, sanitary, and excellent operation at all times.

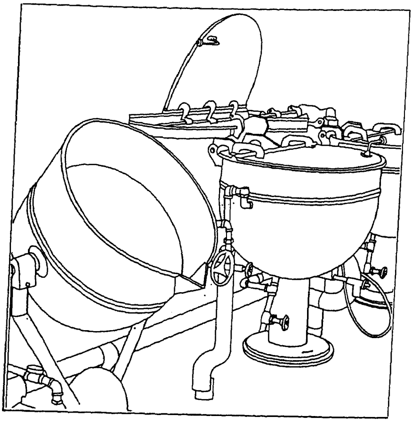
As a Utilitiesman, you may help inspect galley equipment to determine the type of maintenance and extent of repairs (if any) required to keep the equipment in safe, efficient operating condition. To avoid exceeding your authority, remember the medical department is responsible for conducting sanitary inspections, and the supply department is responsible for preparing food and keeping food-handling equipment and spaces clean.

COPPERS

Coppers require, as a minimum, monthly inspections. An annual preventive maintenance inspection is also important. A few factors for inspecting direct-steam connected types of coppers are given below. Incidentally, the Navy also uses a gas-fired type of copper, but, we are primarily interested here in the direct-steam connected type. (See fig. 11-1.)

When making a MONTHLY inspection, check the drawoff faucets, valves, and piping for leaks. Check the steam pressure-reducing valve to ensure it is in good condition and functions properly; lubricate the hinges of the cover with mineral oil.

In the ANNUAL inspection, check the copper for leaks, cracks, and dents. Examine the cover, hinges, and latch for warp and alignment. Check the steam and condensate piping, valves, and traps for leaks and obstructions. Remove the safety valves; then clean, lubricate, and calibrate them before replacing them. Remove



48.11(54)

Figure 11-1.—Coppers.

rust and corrosion, if present, using Navy-approved solvents.

Other than visual inspections, each individual piece of galley equipment requires its own type of preventive maintenance. In table 11-1, a recommended schedule for inspection and maintenance of coppers and other steam-heated equipment is provided.

STEAM CHESTS

The escape of steam from a steam chest harms the food being prepared. It also poses a safety hazard to personnel. To ensure steamtight operation, see that the door latches, hinges, and gaskets are kept close-fitting.

A physical preventive maintenance inspection of the steam chests should be made each week. (See fig. 11-2.) As part of this inspection, make sure that the compartment drains are free of obstructions; that the door hinges, locking devices, and shelf drawbars work well; and that the pressure setting of the gauge pressure is correct.

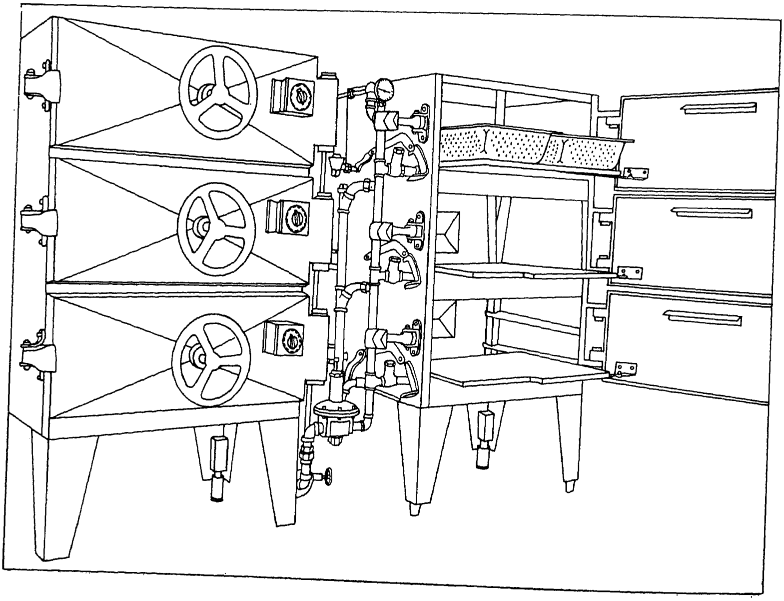


Figure 11-2.—Direct-connected steam chests.

48.19(54)

Table 11-1.—Inspection and Maintenance of Coppers and Other Steam-heated Equipment

Inspection Point	Symptoms	Time	Possible Troubles/Causes	Possible Corrections
Steam jacket	Not heating	When noted	No steam; valve stuck closed; trap malfunctioning	Check steam supply; free stuck valve
Steam jacket	Stays hot	When noted	Valve partly open or scored seat	Repair or replace valve
Steam jacket	Leaks	Monthly	Rapid changes in temperature causing cracks; faulty weld	Raise heat slower; reweld bust or crack
Pipe joints	Leaks	Monthly	Joint made incorrectly; not tight	Unscrew, clean and repair joint
Pipe joints	Corrosion	Monthly	Leaks or condensation	Repair and/or clean
Control valves	Stuck open or closed	When noted	No steam or too much steam; packing too tight or valve frozen	Loosen packing gland or free frozen valve stem
Control valves	Leaks at stem	Weekly	Packing not tight enough	Tighten packing
Condensate strainer	No flow	When noted	Restricted strainer	Clean strainer
Steam trap	Malfunctioning	Every 6 months	Parts dirty or worn	Disassemble, clean, and repair
Lagging	Broken or crushed	Quarterly	Water soaked; stepped on	Replace defective sections
Reducing valve	Incorrect pressure	When noted	Parts dirty or worn	Disassemble, clean, and repair; clean and adjust pressure every 6 months
Safety valve	Stuck open or lifting under pressure	When noted	Leaks or corrosion	Replace or repair valve
Covers	Tight operation	When noted	Hinges dirty	Clean and lubricate hinges
Drawoff valve	Leaks	When noted	Scored	Resurface or replace. DO NOT REPLACE WITH REGULAR GATE VALVE

When a plunger type of valve is used with the locking device, the plunger must be adjusted so the valve is fully depressed when the door is closed. This allows a full measure of steam to enter the compartment. When the door is opened, the valve must function to stop the steam supply completely.

To ensure a tight fit of the doors, replace hinge pins and bushings when they show too much wear. Some full-floating doors are adjustable by means

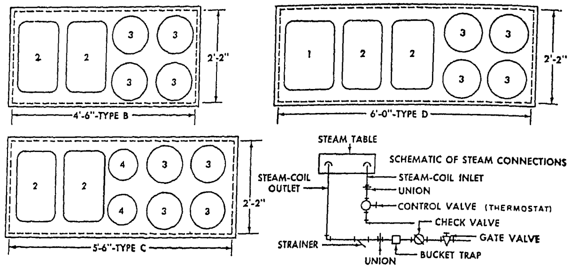


Figure 11-3.—Schematic drawing of a steam table. 54.10

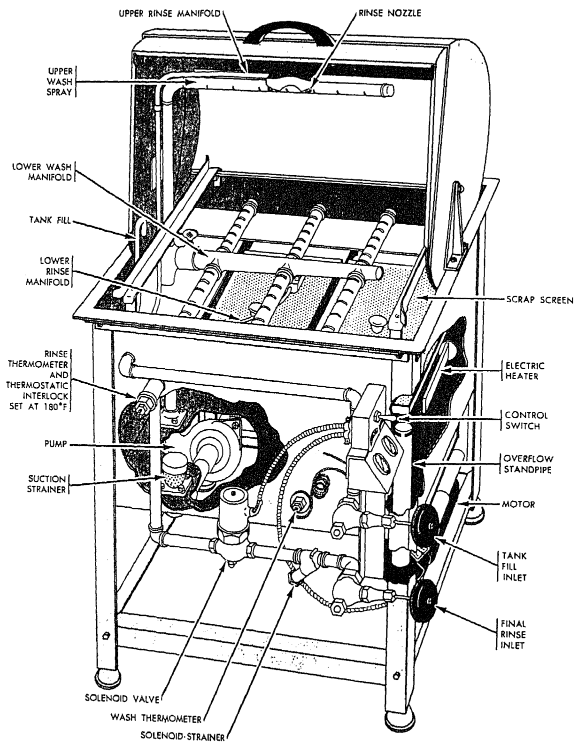


Figure 11-4.—Semiautomatic single-tank dishwasher machine for use in small messes. 48.34(54)

of hexagon-head bolts extending through the door near each corner. When gaskets must be replaced, remove the door from the unit. It is then easier to remove the worn gasket and to clean the channel, since not to do so provides a path for steam leakage. Apply gasket cement, and then force the new gasket into the channel at the corners, working it in toward the center of the sides and ends. You are now ready to rehang the door; but first, place paper along the edge of the door opening to prevent excess cement from adhering to the mating surfaces when the door is closed. Any surplus cement can be cleaned off after it has hardened.

When the door has hexagon-head bolts, adjust them so the closed door touches the steamer evenly, without binding at the corners. Unless you have a good fit, the gasket will cut by the corners of the door and steam will escape.

For inspection and preventive maintenance of the steam service and condensate system, include those items in table 11-1 that apply.

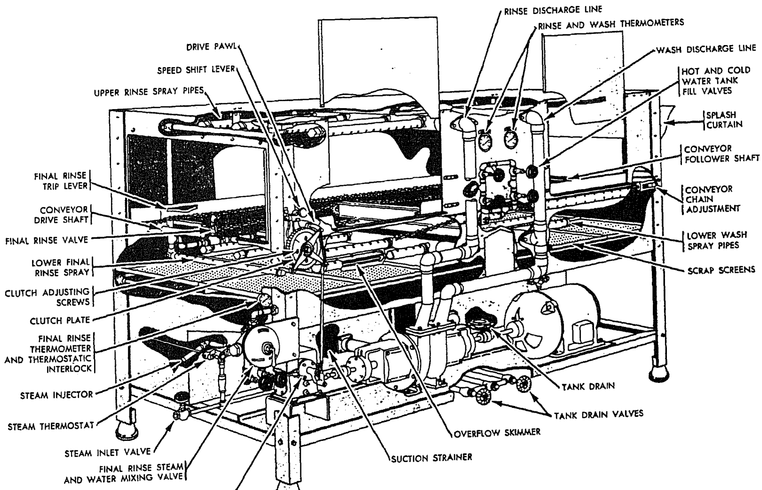
STEAM TABLES

Steam tables should be carefully inspected monthly and yearly. (See fig. 11-3.) In making a monthly inspection, check the water compartment, steam coil, valves, and piping for leaks and corrosion. Check the steam pressure on the gauge, keeping in mind that PRESSURE SHOULD NOT EXCEED MAXIMUM PRESSURE SHOWN ON THE NAMEPLATE. Also, calibrate the temperature control.

When conducting an annual inspection of steam tables, descale the water compartment, examine the top and frame for scale, and check the level of the steam table top. Then check the thermostat with a mercury thermometer. The thermostat must be accurate to within 5 °F either plus or minus. Remove the rust and corrosion within the water compartment with solvent, and paint the bare spots with heat-resistant aluminum paint. Use table 11-1 to check other items that apply to this equipment.

DISHWASHING MACHINES

From time to time, you may be called upon to adjust dishwashing machines which have become defective. (See figs. 11-4 and 11-5.) Some of the most common difficulties, the usual reasons for their occurrence, and



48.35(54)B

Figure 11-5.—Cutaway view of a double-tank automatic dishwasher.

Table 11-2.—Troubleshooting for Dishwashing Machine

Trouble	Probable cause	Possible remedy
Dish racks slide off chain conveyor.	Change of tension on either chain.	Reset idler sprockets to proper tension on each chain.
Water pressure too low.	Spray nozzles or slot plugged. Strainer baskets plugged. Slipped belts on pumps.	Dismantle spray assembly. Wash out piping; clean parts. Disassemble and clean strainer. If belts are frayed or torn, replace them. Adjust tension by resetting idler pulley or by moving motor on sliding base.
Water splashing on floor or into wrong compartment.	Leaks around doors; torn curtains or curtains not in proper position.	Realign door. Repair or replace gasket. Repair or realign curtain. Readjust spray to keep it within limits of tank.
Rinse water temperature is less than 180 °F.	Insufficient heat from booster heater.	Remove scale from steam coil. Correct leaking fittings. Adjust gas burners. Calibrate or replace thermostat.
Spot or film on eating utensils after final rinse.	Wash water saturated with grease. Dirty tank. Weak sprays in wrong direction. Improper detergent mixture.	Stop operation and clean all equipment. Adjust speed of conveyor. Examine spray equipment. Clean nozzles, spray pipes, scrap trays, and strainers. Check piping for leaks. Check to see if valves are operating properly. Examine pump. Clean impeller if necessary.

possible remedies for them are listed in table 11-2.

Now and then, descale deposits from within the machine, the piping, and the pumps. You can fill the tank halfway with hot water, add an approved cleaning solution, fill the tanks to overflowing, and then operate the machine for 30 minutes at high temperature with trays, spray arms, and curtains in place. Next, drain the tanks and fill them with hot water and run the machine for 5 minutes. This rinsing should be repeated several times to make sure all the cleaning solution has been removed.

Dishwashing machines and accessories should be lubricated according to the manufacturer's instructions. This is especially true in the selection of grades and viscosities of oil used, the levels at which the oil is to be maintained, and the places to be oiled. All damaged or missing lubrication fittings should be replaced. The grease cups on the drive end, connecting rod, and the rinse lever should be turned about once each quarter and refilled when empty. The revolving wash arms and valve stems should have a few drops of light oil applied to them about once each quarter.

CAUTION: Be sure to turn off the power before lubricating the equipment.

Because of limited space, this chapter does not attempt to provide all the necessary details concerning the parts and accessories of dishwashing machines. Study the manufacturer's manual for the type and make of machine concerned. A brief treatment on some of the machine parts and accessories which should be maintained and serviced regularly is given below.

1. Repair or replace the torn or worn curtains.
2. Straighten the warped pans so they stay flat in the machine.
3. Replace the packing with new material of the same type and size. Do not overpack the packing gland. This causes binding of the shaft.

4. Replace the broken or damaged thermometers. Check the accuracy of the thermometer by measuring the water temperature with a high-grade thermometer and comparing results with a thermostat setting. The thermostat should be set for a wash water temperature of 138 °F to 145 °F and rinse water for a temperature of 180 °F or above.

5. Defective conveyors should be properly adjusted or replaced. Check the nylon covering of steel parts; replace them when they are worn or torn.

6. The inspection doors of wash and rinse compartments should be kept tight at all times. Straighten or replace bent or loose doors.

7. Check the chains and pulleys of counter-balanced doors. Apply oil regularly to moving parts.

8. Check the dish racks for bent or warped surfaces and replace broken parts.

9. Inspect the utility fittings, such as steam coils, traps, heating elements, gas burners, and all thermostats. Follow the manufacturer's repair instructions. Usually, you have to detach these component parts and take them to the maintenance shop for repairs.

10. Ventilating hoods are installed above or at ends of dishwashing machines and are equipped with fans. By these means, moisture and heated air created by hot water in the machine are collected and exhausted. All surfaces of the hood should be frequently checked for corrosion and rust. Remove the rust with solvents and paint over corroded areas with two coats of rust-resistant paint. In selecting a solvent, use the air-inhibited sulfamic acid type according to the manufacturer's instructions. Never use steel wool for cleaning interior surfaces because small particles may contact dishes and eventually become embedded in food. Check the ventilating fan for grease and other impurities that should be scraped off with a knife. Fan accessories, such as baffles, clampers, vanes, access doors, louvers, registers, protective grilles, and bird or insect screens, should all be checked and corrected for rust and corrosion. Any of these items that have become loosened by vibration should be tightened, and worn or missing parts replaced.

With regular inspection and lubrication, with repairs and adjustments made as necessary, and with strict observance of the manufacturer's operating instructions, these machines will last a long time. To ensure they receive the required attention, set up a regular schedule of inspection. Monthly and annual inspections may be satisfactory in many cases.

MONTHLY inspection and maintenance of dishwashing machines should include the following items:

1. Check the lubrication of bearings, gearboxes, chains, and sprockets; lubricants should be added, if required.

2. Check the drive V-belt tension and alignment, flexible couplings, chains, and sprockets.

3. Have an electrician check the electrical components for proper functioning and safety features, including proper grounding.

4. Ensure the machine and the tables are level; check for misalignment of parts, loose parts and leaks, and unusual noises.

5. Check the piping system for faults.

In making an ANNUAL INSPECTION of dishwashers, give careful attention to the following items:

1. Check the frames for adequacy of support; tightness of casings, seams, joints, and counterweights; evidence of corrosion; watertightness of doors, hinges, and gaskets; and correctness of clearance and alignment.

2. Check the pumps and impellers for corrosion or extreme wear of parts. Disassemble them, clean all parts thoroughly, and repair or replace badly worn parts. Reassemble and adjust. Lubricate all parts requiring lubrication.

NOTE: Be sure and tag the dishwasher, stating the date of the current inspection, repairs made, and the date of the next inspection.

RANGES

Observing a schedule of monthly and annual inspections ensures the safe and efficient operation of a range, including the oven, broiler, griddle, and so on. Some of the major items that should be covered in the inspection of oil- and gas-fired equipment are given below.

As part of the MONTHLY inspection, check the pipe for leaks, clean and lubricate the motors,

and check the burner flame. Remember, the burner should give off a blue flame when the air-oil mixture is correct. A flue-gas analysis should be performed to find the proper fuel-air mixture.

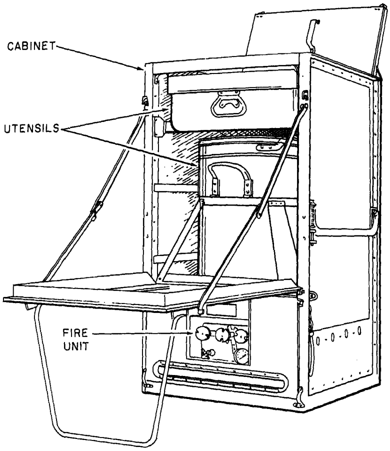
Also, check the equipment for alignment and fit of doors, for sliding action of racks, and for levelness.

The ANNUAL inspection of oil- and gas-fired equipment should include a check on all parts for damage, corrosion, and lack of paint. Remove the rust with solvents, and paint the bare spots with heat-resistant aluminum paint. (NOTE: If bare spots total more than 20 percent of the entire surface, paint the equipment.) If the accuracy of the thermostat cannot be adjusted to within 5 °F accuracy, replace it with a new thermostat. Clean soot deposits and jet openings and repair or replace leaking piping. Clean and tighten the nuts and bolts.

See table 11-3 for a troubleshooting chart covering the maintenance of ranges, ovens, and broilers.

FIELD RANGE

As a Utilitiesman, you need to know how to maintain, repair, and troubleshoot the field range. This manual does not list all you need to know about the field range. A gas-fired field range is shown in figure 11-6. The location and



48.61

Figure 11-6.—Field range with fire unit in position for cooking.

Table 11-3.—Troubleshooting Chart for Ovens, Ranges, and Broilers

Trouble	Probable cause	Possible remedy
	OIL-FIRED OVENS	
Motor will not start.	Blown fuse.	Replace fuse.
	Thermostat set below baking chamber temperature.	Set thermostat above oven temperature.
	Solenoid valve activated.	Replace solenoid valve.
	Solenoid out of order.	Clean out foreign particles; look for evidence of wear.
Motor runs but oven fails to light.	Fuel tank empty.	Fill tank.
	No ignition because of carbon formation.	Clean carbon from electrodes.
	No ignition because of damaged transformer.	Replace transformer.
	Clogged fuel nozzle.	Clean nozzle tip and screen. Also clean screens in fuel pump unit. If water and sludge are found in screens, fuel tank must be pumped out.

Table 11-3.—Troubleshooting Chart for Ovens, Ranges, and Broilers—Continued

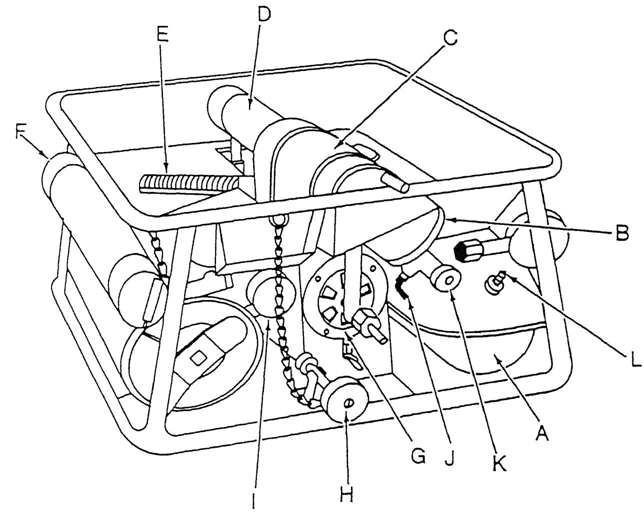
Trouble	Probable cause	Possible remedy
OIL-FIRED OVENS—Continued.		
Combustion flame is disorganized and smoky.	Closed damper. Heavy soot deposits in flue pipes.	Open secondary air damper door. Remove flue pipes and clean.
Uneven cooking.	Secondary air damper door is too far open or too near shut.	Adjust secondary air door. Open wide for fast rates of firing; Open slightly for slow rates of firing.
Difficult ignition.	Oil supply is too low. Oil supply is shut off by solenoid valve.	Open oil regulating valve. Push reset valve on units having such equipment.
Burner starts and functions properly but fails after short intervals.	Dirty burner openings. Air leaks in suction line. Clogged strainers. Oil tank vent obstructed. Controls out of order or improperly adjusted.	Clean parts of burner. Repair leaks. Clean strainers. Remove obstructions. Check controls. Adjust controls properly.
Burner puffs when started.	Poor or delayed ignition. Insufficient draft.	Clean the nozzle. Examine ignition assembly and test for short circuit. Adjust electrodes to proper position. Adjust damper. Examine flue passages and chimney for obstructions.
Flame pulsates when burner runs.	Insufficient draft. Downdraft in chimney or fluctuating draft.	Check and adjust damper. Move air diffuser forward or backward to change air turbulence at nozzle tip. Examine flue passages fŏr obstructions.
Smoke in combustion chamber or smoke from chimney.	Improper or defective nozzle. Nozzle partially clogged. Insufficient air.	Replace nozzle. Clean nozzle. Increase air intake opening. Provide adequate air supply to burner space.
Carbon forms in combustion chamber.	Oil spray impinges on walls. Excessive oil burning rate.	Check nozzle to see if correct model. Clean nozzle, if necessary. Reduce oil pressure or install smaller size nozzle.
Fire is on one side.	Nozzle is damaged or dirty.	Clean or replace nozzle.
High oil consumption.	Too little air. Dirty heat-absorbing surfaces. Excessive draft. Leak in oil storage tank.	Increase air intake. Clean ducts. Reduce draft by adjusting damper. Repair tank.
Solenoid valve fails to function.	Defective solenoid valve. Thermostat damaged. Defective connections. Emergency bypass valve open. Dirty solenoid valve.	Replace solenoid valve. Replace thermostat. Repair connections. Close emergency bypasss valve. Disassemble valve and clean parts.

Table 11-3.—Troubleshooting Chart for Ovens, Ranges, and Broilers—Continued

Trouble	Probable cause	Possible remedy
OIL-FIRED OVENS—Continued.		
Pilot flame inoperative or too low.	Setscrew adjustment too tight on back of solenoid valve. Fuel passage clogged.	Adjust setscrew to increase fuel for pilot flame. Remove solenoid valve pilot flame setscrew and clean both stem and port.
Oven overheats.	Thermostat damaged. Solenoid valve plunger does not drop to shutoff position.	Replace thermostat. Tap body of the valve gently. Clean solenoid valve and replace.
Oven underheats.	Fuel line clogged. Fuel shutoff valve not fully opened at tank. Vaporizing parts full of carbon.	Clean fuel line. Open the shutoff valve to the maximum. Remove all carbon.
GAS OVENS AND RANGES		
Fails to ignite.	Insufficient or no pilot flame. Main gas valve or shutoff valve adjacent to oven is off. Air shutter completely closed.	Light and/or adjust pilot flame. Turn on gas valve. Adjust air shutter.
Oven does not heat fast enough.	Gas input too low or not in proper adjustment. Cooling damper open.	Clean burner. Adjust burner controls. Close cooling damper.
Uneven cooking.	"Soft" flame. Too much draft pulling heat out through flue. Doors do not close tightly.	Adjust bypass flame. Remove excessive draft. Remove accumulation around door edges.
No gas.	Main service valve closed. Solenoid valve not opening.	Open main service valve. Clean solenoid valve.
Constant "burning."	Too much draft. Faulty thermostat.	Remove excessive draft. Replace thermostat.
Temperature rises when oven is not in use.	Low flame setting is too high.	Cut low flame to a minimum. Shut off burner when oven is not in use, leaving pilot on.
Fumes in room.	Faulty chimney, or back draft, or improper gas adjustment. Fan running in room with doors and windows closed causing vacuum.	Inspect and correct defective ventilation system. Open window or door to eliminate vacuum.
Flare back on turn-down.	Bypass flame too low.	Adjust bypass flame.

description of the major components of the burner unit are shown in figure 11-7.

Keeping the field range in a constant state of readiness is important to everyone in the field. This is accomplished by performing preventive maintenance checks and services quarterly or every 250 hours of operation, whichever occurs first. Table 11-4 contains a list of preventive maintenance



A. FUEL TANK - CONTAINS FUEL TO OPERATE BURNER.
B. PREHEATER - HEATS GENERATOR, WHICH WILL THEN CHANGE FUEL TO GAS VAPOR.
C. PREHEATER SHIELD - HELPS GENERATOR HEAT UP FASTER.
D. GENERATOR - FILTERS AND CONVERTS LIQUID FUEL INTO A GAS VAPOR.
E. BURNER - SPREADS OUT THE FLAME UNDER COOKING POTS OR PANS.
F. SPARE GENERATOR - REPLACEMENT FOR DEFECTIVE GENERATOR.
G. AIR SHUTTER - ADJUSTS AIR INPUT TO BURNER.
H. GENERATOR KNOB, FLAME VALVE - FUEL ADJUSTMENT TO BURNER.
I. AIR PRESSURE GAUGE - INDICATES PRESSURE IN FUEL TANK.
J. ORIFICE CLEANER - CLEANS ORIFICE IN PREHEATER VALVE.
K. PREHEATER VALVE - INPUTS GAS TO PREHEATER.
L. AIR VALVE - HAND PUMP ATTACHMENT USED TO PRESSURIZE FUEL TANK.

54.603

Figure 11-7.—Location and description of the major components of the burner unit.

Table 11-4.—Organizational Preventive Maintenance Checks and Services Quarterly Schedule

Item No.	Item to be Inspected	Procedures
		Cabinet Assembly
1	Lid	Inspect for improper closing, cracked or broken hinges, and defective brace or handle. Replace a defective lid. Inspect the lid hinge retainer and replace if necessary.
2	Lifting Handle	Check for breaks, binding, and loose or missing rivets. Replace a defective lifting handle.
3	Accessory Items	Inspect all accessory items for serviceability; repair or replace any unserviceable items.
		Burner Assembly
4	Top and Bottom Shields	Inspect for cracks, bends, and missing or distorted springs. Repair or replace a damaged part.
5	Spare Generators	Inspect for dents and broken, loose, or missing fittings. Check for leaks. Replace a defective spare generator.
6	Air Valve	Inspect for leaks and improper operation while pressurizing the unit. If valve leaks, shut unit down and replace valve.
7	Fuel Tank	Inspect for leaks from drain plug. If defective, replace. Check fuel tank for cracks, broken welds, damaged threads, and other leaks. Replace a damaged fuel tank. Check fuel filler cap for cracks, damaged threads, defective gasket, and leaks. Replace a defective cap or gasket.
8	Preheater	Inspect preheater valve for leaks and improper operation. If valve leaks, shut down unit. Check for leaks between valve stem and packing nut. Tighten packing nut or repack valve as required. Replace a defective valve. Inspect the preheater head and shield for bends and breaks. Check the head for loose mounting. Inspect the orifice cleaning control for binding or improper operation. Inspect the preheater head bushing for damaged threads. Replace or repair the preheater.
9	Main Generator	Inspect generator flame valve for leaks and improper operation. If valve leaks, shut down unit. Check for leaks between valve stem and packing nut. Tighten nut or replace valve as required. Inspect generator for carbon deposits, dents, breaks, and loose connections. Replace a defective generator.
10	Burner	Inspect for breaks, loose mounting, and clogged slots. During operation, check for erratic burning and blue or yellow flame. Replace a defective burner.

Table 11-4.—Organizational Preventive Maintenance Checks and Services Quarterly Schedule—Continued

Item No.	Item to be Inspected	Procedures
11	Air Pressure Gauge	Inspect for breaks, broken glass, or bent needle. Check with tank filler cap removed to determine the gauge reads zero. Then check after filling tank and closing tank filler cap, the gauge will indicate a steady even increase in pressure as the tank is pressurized with the hand pump. If the gauge will not pass above visual inspection and tests, the gauge shall be replaced.
12	Air Control Shutter and Mixing Chamber	Inspect shutter for binding, loose mounting and damaged control lever. Tighten mounting hardware. Inspect mixing chamber for cracks. Replace any defective parts. **WARNING** Use extreme care when using the air compressor to pressurize the fuel tank.
13	Safety Valve Device	Inspect device for improper operation, leaks, loose hardware for bent tubing. Safety system for proper functioning. DRAIN FUEL TANK. Using air compressor, pressurize tank to approximately 60 (PSIG) where the safety valve should operate. After the safety opens, pressure should drop rapidly to approximately 35 ± 10 PSIG at which point the safety valve should close. Using soapy solution, check for leaks. Set burner unit on end and turn fuel filler cap slowly counterclockwise to release air pressure. Tighten any loose hardware. Replace defective device.

checks and services. Table 11-5 is a listing of possible malfunctions that may occur in the field range outfit. It will help you in diagnosing and correcting unsatisfactory operation or failure of the field range outfit. An excellent source of information is listed in the references at the end of this chapter.

BAKERY OVENS

Routine maintenance of bakery ovens requires weekly, monthly, and annual inspections.

WEEKLY inspections should include adjustments of heating units for proper fuel-air mixtures and constant operating temperature. (See fig. 11-8.) Check the pilot flame of the gas-fired ovens and adjust it, if necessary, so the burner gas ignites without wasting fuel and the flame is not blown out by the flue draft; adjust the fuel-air mixture to produce a blue flame. Check the operation of the purging fan and the flame failure devices. Clean the soot and dirt from the pilot and gas burner. Check the oil supply for leaks and stoppages and clean the strainer basket of oil-fired ovens. Examine the operation of the electric-ignition and flame-failure devices, and repair them if necessary. Adjust the oil burner for proper spread of fuel across the combustion chamber and for proper fuel-air mixture to maintain a blue flame. Examine the operation of dampers and clean and adjust them if required. Check the settings of automatic temperature and humidity controls; reset the settings of the thermostat and humidistat if necessary.

MONTHLY inspections should cover inspection of the conveyor and drive, the adjustment of loose chains, belt tension, and other

MALFUNCTION
TEST OR INSPECTION
CORRECTIVE ACTION

1. **FUEL SYSTEM FAILS TO MAINTAIN PRESSURE.**

Step 1. Fuel filler LEAKS.
Remove filler cap and replace gasket.

Step 2. Air valve defective.
Replace air valve.

Step 3. Fuel tank defective.
Replace fuel tank.

Step 4. Safety valve does not reseat.
Replace safety valve device.

2. **PREHEATER FAILS TO IGNITE.**

Step 1. Preheater fuel feed tube assembly is damaged or missing.
Repair or replace fuel feed tube assembly.

Step 2. Preheater generator defective.
Replace preheater generator.

3. **BURNER FAILS TO IGNITE.**

Step 1. Preheater generator defective.
Replace preheater generator.

Step 2. Generator is defective.
Replace generator.

Step 3. Feed tube assembly missing, clogged or dented.
Shut down—allow to cool—clean feed tube assembly or have replaced.

4. **YELLOW BURNER FLAME.**

Step 1. Generator flame valve is defective.
Repack or replace valve.

Step 2. Generator is defective.
Replace generator.

5. **BURNER FLAME TOO LOW.**

Step 1. Generator defective.
Replace generator.

Step 2. Generator flame valve is defective.
Repack or replace valve.

6. **FUEL LEAKS AT GENERATOR VALVE.**

Valve or valve packing is defective.
Repack or replace valve.

7. **FUEL LEAKS AT PREHEATER VALVE.**

Valve or valve packing is defective.
Repack or replace valve.

8. **PRESSURE RISES ABOVE SAFE LIMIT ON AIR PRESSURE GAUGE.**

Step 1. Fuel tank too full.
Fill with only 8 quarts (7.6 liters) of gasoline.

Step 2. Air pressure gauge is defective.
Replace gauge.

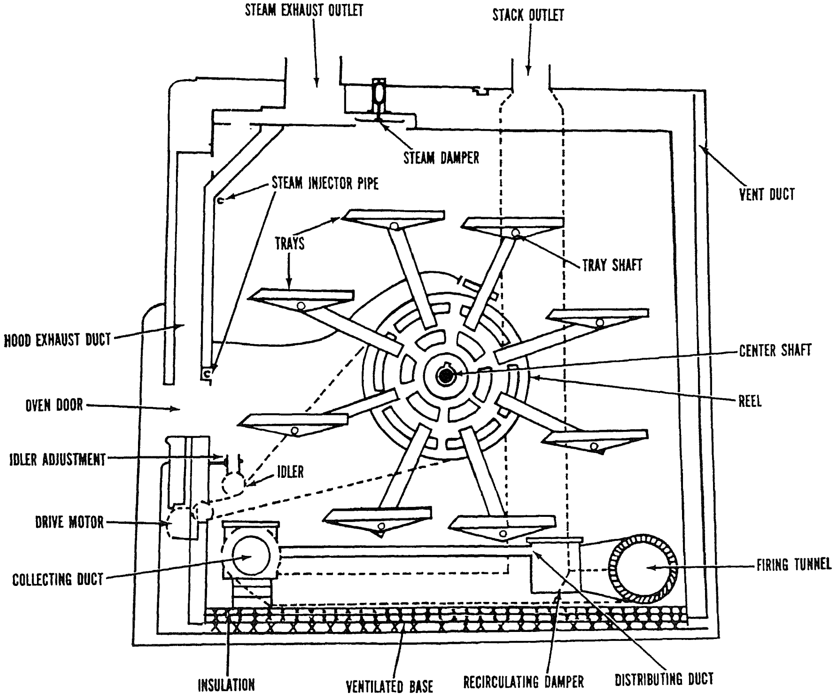


Figure 11-8.—Reel oven.

components that may be misaligned. Adjust the chains of the V-belt tension by moving the idler sprocket or sliding motor base. Check the lubrication of gearboxes, bearings, and moving parts. Examine the oven top and walls for cracks and breaks; make the repairs if necessary to ensure tightness.

When making an ANNUAL inspection of bakery ovens, drain, flush, and renew the lubricant in the gearboxes. Check the sprockets, gears, and bearings and renew the lubricant according to the manufacturer's instructions. Have electrical checks made of the insulation resistance of motor windings, controls, and wiring. Clean all contacts of the controls. Remember that electrical work should be done by a qualified electrician.

INTERCEPTORS AND GREASE TRAPS

Removal of grease from greasy wastes is necessary if the sewage system is to function properly. One way grease is collected is by ceramic or cast-iron grease interceptors installed inside mess halls. Among the types of interceptors you may encounter is the Zurn interceptor shown in

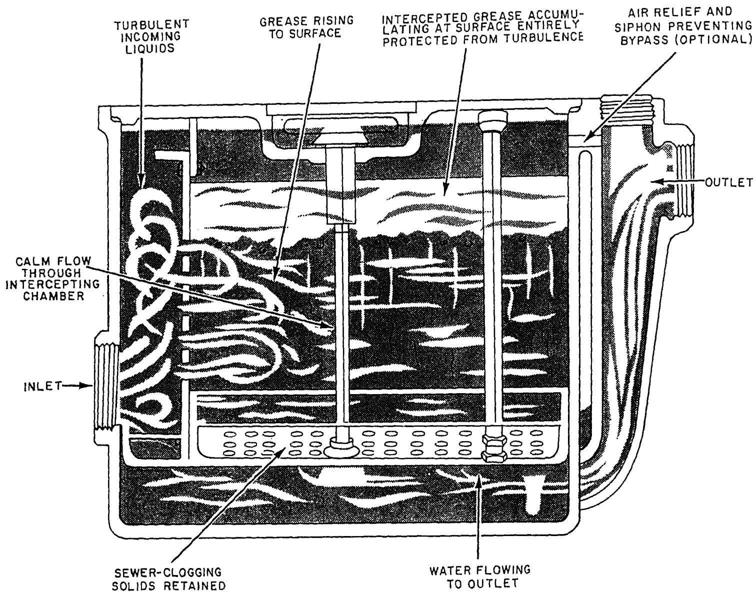


Figure 11-9.—Zurn interceptor.

figure 11-9. Another way of collecting grease is to use concrete or brick grease traps outside of buildings. Mess personnel usually clean the inside interceptors but you may have to clean the outside traps. When inside grease interceptors are maintained properly, they should collect most of the grease from the waste. They may need cleaning once each day.

Remember that outside grease traps are intended to serve kitchen plumbing fixtures and equipment only. So, they should never be connected to soil and waste lines from toilet rooms. To help ensure proper functioning, clean grease traps at least once a week. Since accumulated odor-forming solids cause septic action within a short time, remove all solids each time the traps are cleaned. The following procedures provide a guide for cleaning outside grease traps:

1. Skim grease from the surface of the trap using an ordinary perforated sewer scoop, and place it in suitable containers for disposal.

2. Remove as much odor-forming material as possible with the same scoop. Treat this refuse as disposable.

3. Pump out the liquid from the traps every 3 months, and remove all sediment from the sidewalls and the bottom if necessary.

REFERENCES

Building Maintenance—Galley Equipment, NAVFAC MO-119, Naval Facilities Engineering Command, Alexandria, Va., 1963.

Operator, Organizational and Direct Support Maintenance Manual Including Repair Parts and Special Tools List for Range Outfit, Field, Gasoline, Model M59, TM 10-7360-204-13 & P, Headquarters, Department of the Army, Washington, D.C., 1988.

CHAPTER 12

LAUNDRY EQUIPMENT

Learning Objective: Identify the procedures required for installing, maintaining, troubleshooting, and repairing laundry equipment.

Laundry equipment varies from one activity to another, depending upon such factors as the size of the laundry and the differences in individual types of equipment produced by various manufacturers. Some common types of equipment used in most laundries are washers, extractors, and drying tumblers.

One type of laundry unit you may encounter in your work is shown in views A, B, and C of figure 12-1. This laundry unit is mounted on three skids that are fitted together in assembling the unit. On one skid is the washer unit which consists of two 75-pound 26- by 26-inch end-loading washers and one 30-inch top-loading extractor. View C shows the extractor and the back of the washers more clearly. The middle skid has the dryer unit, which consists of two 42- by 42-inch steam-heated drying tumblers, one air compressor, an electric-driven motor, and one stainless steel surge tank. The other skid has the boiler unit; it consists of an oil-fired 33-horsepower steam generator with a return hot well, a water softener, and a 350-gallon hot-water storage tank. This laundry unit can wash and fluff dry 225 pounds (dry weight) of laundry per hour.

In the following sections, information is provided about the installation, maintenance, and minor repair of laundry equipment. This information is not intended to furnish all the details you need to know concerning installation, maintenance, and repair of washers, extractors, drying tumblers and steam generators. For specific information, you should always refer to the instruction manual provided by the manufacturer of the equipment.

WASHER

The purpose of a washer is to wash clothes and other suitable materials. The washing process is a series of baths during which soil is loosened from the materials, suspended in the water, and finally rinsed away. Several baths are usually necessary to remove the soil completely.

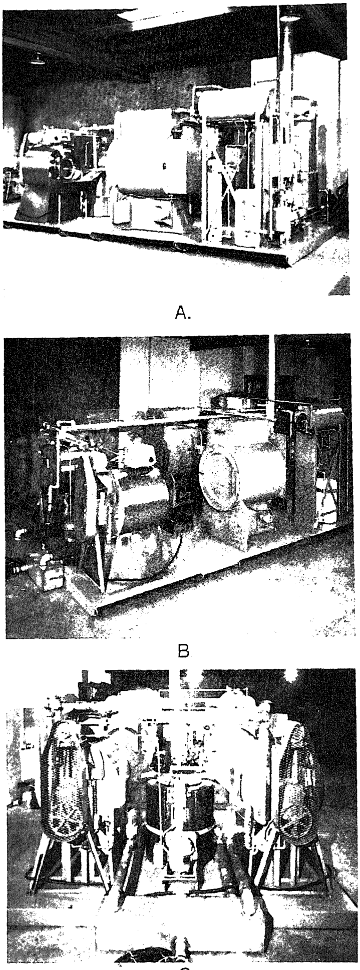
One type of washer used at Navy activities is the Milnor end-loaded, fully automatic washer, shown in figure 12-2. This Milnor washer is discussed in the paragraphs that follow. The washer is provided with a removable FORMULA CHART which can be easily changed at the discretion of the operator.

Each formula chart provides a full 88 minutes of operation if desired. Two or even three formulas may be cut on the same formula chart as long as the total elapsed time of the formula does not exceed 88 minutes. The operator has a clear view of the formula during operation. Marker labels affixed to the formula show the operation in progress and which supplies are needed when the timer signals.

The washer is also equipped with a Miltrol timer to carry the washer through a complete cycle by following the formula cut in the chart, accurately and automatically filling, dumping, maintaining proper water level, supplying proper water temperature for each operation, and signaling the operator each time supplies are required.

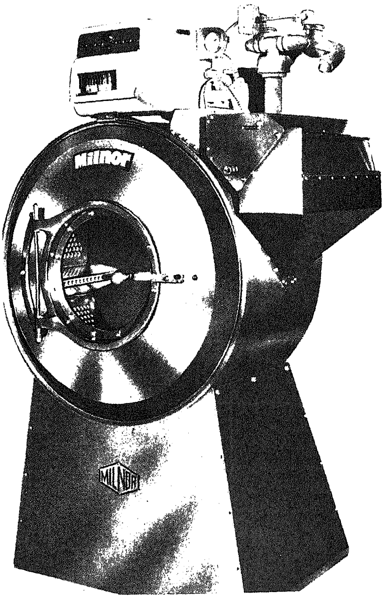
The washer has an automatic supply injector unit that consists of five compartments. Various supplies are placed in these compartments at the start of the washing cycle. At the proper moment, the supplies are flushed from the compartment into the washer. The compartments are numbered one through five, starting at the front of the washer.

The two supply compartment nearest the front of the washer (compartments one and two) are intended for starch, dry soap, and/or alkali. Any dry additive normally used in a suds bath (such



54.604

Figure 12-1.—Skid-mounted laundry unit.



Courtesy of Pellerin-Milnor Corporation

22.10(54F)

Figure 12-2.—Washer.

as regenerator, and so forth) may also be injected from compartments one and two.

The three remaining supply compartments (compartments three, four, and five) are intended for supplies, such as bleach, sour (acid), and blue.

Machines equipped with automatic supply injection may be operated automatically at any time without the automatic injection feature by merely changing formula charts. If desired, two formulas—one using automatic injection and the second without automatic injection—can be cut on the same formula chart and the machine operated with or without injection.

Machines equipped with automatic supply injection may also be operated manually at any time. To operate manually, however, turn the chart to the uncut position.

When required, Milnor washers can be supplied with an electrically operated tempering control to control the water temperature admitted

to the washer thermostatically. This automatic device consists of the necessary circuit and a control thermostat mounted in the discharge from the hot- and cold-water valves. The thermostat senses the mixture temperature and alternately opens and closes the hot- and cold-water valves, maintaining accurate control of the temperature of the water admitted to the washer. Since the thermostat senses the temperature of the incoming water rather than the temperature of the final bath within the cylinder, the actual final temperature depends, to some extent, upon the temperature of the previous operation; hence, if hotter water is admitted to the washer after a hot operation, the hot-water temperature tends to be somewhat hotter than the temperature set on the thermostat. Conversely, if hotter water is admitted into the washer after a cold bath, the final temperature tends to be somewhat colder.

Milnor washers, when required, can be furnished with a device to inject supplemental steam automatically when called for by the formula chart and raise the water temperature above that available from the hot-water source. This device can also be used to maintain minimum hot-water temperature in the washer when the normal hot-water source is unable to generate enough hot water to keep up with the hot-water demand of the plant, or to raise the water temperature near the boiling point. Washers furnished with this device are equipped with an automatic steam injection valve, a diffusing nozzle, and a temperature-sensing thermostat mounted in the shell of the washer for controlling the final temperature.

The thermostat has temperature markings on the dial and may be adjusted at will. These temperature markings are approximate only; the actual temperature within the cylinder at the expiration of steam injection can vary about 10°F from the setting on the thermostat. So, these thermostats should be set by referring to the thermometer furnished on the washer.

INSTALLATION

When installing the Milnor washer, follow the general instructions below.

Install the washer on a steady, level floor or foundation. Make sure the machine is properly bolted down to prevent vibration. When pushing or moving the washer to its foundation, always push against solid parts of the machine, such as the shell or base—never against the belt guard, valves, electric controls and so on.

Now, assemble the water inlet valves on the rear shell of the washer. (The water inlet valve assembly and two water inlet valve strainers are shipped inside of the washer.) Assembling the inlet valves consists of plugging in a twist-lock connection to the rear of the Miltrol timer, or plugging bullet connectors into rubber sleeves as shown on the inside of the Miltrol box. Incidentally, on some models, the inlet valves are permanently attached and wired to the control and do not require installation.

Connect the hot and cold waterlines to the hot- and cold-water inlet valves. (The hot-water valve is on the left, and the cold-water valve is on the right when you face the front of the washer.) Install one of the strainers in each of the waterlines just ahead of the solenoid valve. Install strainers with the direction of the flow of water in the same direction as the arrow on the strainer. Note that some machines have water valves that do not require strainers, so when this type of valve is used, no strainers are shipped inside of the washer cylinder.

Some models are furnished with a "Steam Boil" circuit to allow any or all of the washing operations at boiling temperature. In such cases, connect the steam line to the steam solenoid valve near the bottom of the washer shell at the rear of the machine.

To eliminate water hammer when the inlet valves close, connect the inlet valves to the water main with a short piece of rubber hose (about 15 to 24 inches long) between the water main and the upstream side of the strainers. The elasticity of the rubber hose prevents the pounding noise that might otherwise occur every time an inlet valve is closed.

Water inlet valves are rated to handle a maximum of 90-psi pressure. A pressure-reducing valve should be used to limit water pressure when the pressure exceeds this figure. The steam valve (when furnished) is rated to handle a maximum of 110-psi pressure, and a pressure-reducing valve should be used to limit steam pressure when it exceeds this figure.

Connect the pressure supply for the automatic drain valve to the air line or to the cold waterline. The automatic drain valve requires a minimum of 25-psi pressure AT ALL TIMES. Since the water pressure in a pipe next to a valve always drops when the valve is opened, you must connect the drain valve water connection to the cold waterline at the point farthest ahead of all of the water inlet valves. When the drain valve opens each time a water inlet valve is opened, the

water pressure is low. The water consumption of other machines in the plant can also cause the automatic drain valve to malfunction. Sometimes, but not always, the effect of low water pressure can be eliminated by installing a small, sensitive check valve directly ahead of the strainer in the automatic drain valve pressure connection line. Also, some Health Board regulations may require a check valve to be installed at this point. If it is impossible to correct the water pressure, the drain valve may be operated by air pressure.

NOTE: Some models are equipped with electric drain valves that do not require air or water pressure connections.

Connect the drain line to the connection in the BOTTOM of the automatic drain valve. The threaded connection in the side of the automatic drain valve is a cleanout hole only.

Carefully check the washer nameplate to ensure electrical specifications conform to the electrical service available. Have a Construction Electrician connect the terminals marked "LINE" in the Miltrol timer to power lines in the plant. You do not have to run a secondary voltage to the machine to operate the automatic controls. The Miltrol timer operates on the same input voltage as the rest of the machine (motor, reversing control, and so forth) and was wired completely at the factory.

The Miltrol timer is equipped with a step-down transformer to lower the voltage at the contact fingers to 24 volts. Some electrical components in the timer operate on 24 volts (the lamps, timer relays, water valves, and so forth). Other electrical components operate on the same voltage as the motor (such as the reversing control contactors and cam timer, the dump valve, and others). You may refer to the wiring diagram pasted in the top of the timer box to determine on which voltage an electrical component operates.

Try to provide a line disconnect switch for each washer, so any washer in your installation can be turned off for repairs without affecting the operation of the others.

Adjust the level control for the desired high and low water levels. A high and low level is normally recommended by the manufacturer, and the level control is set at the factory to deliver the approximate water depths. However, the final adjustment must be made in the field.

On machines equipped with gearbox drives, consult the special instruction sheet for details on the care of the gearbox before running the washer.

Connect the supply injector unit to a source of water for flushing. Connect directly from the waterline to the pressure regulator at the rear of the machine. Always use at least as large a pipe as the pressure regulator connection. Use one size larger if the pipe run is more than 5 feet. When the water piping for the supply injector is too small, the supply injector does not flush the supplies properly. Also, small pipes magnify water hammer when the supply injector valves shut off and cause early failure of the rubber valve seats in the supply injector valves.

When available, hot water should be used for flushing but only if your hot-water source is dependable, has at least 20-psi pressure, and does not occasionally boil over and produce steam in the hot waterline. If hot water is not available, use cold water.

Five solenoid valves are within the supply injector. These valves can handle a maximum of 30 psi. They are adequately protected against higher pressure by the pressure-reducing valve that has been properly set at the factory to deliver between 25 to 28 psi. Increasing the pressure above 28 psi may cause the flush valves to fail to open and may even cause the electric coils to burn out. Be sure to check the pressure gauge and reset it to 25 to 28 pounds, as vibration and/or handling in shipment may cause the regulator to get out of adjustment. Do not exceed 28 pounds of pressure. Make a supply injector valve open two or three times, then set the pressure when there is no flow of water through the supply injector.

Note that under certain peculiar and infrequent combinations of incoming water pressure and upstream piping outlines, the supply injector pressure regulator may chatter while flushing supplies into the machine. Should this occur, check the injector pressure gauge to make sure the regulator is set for 25 to 28 psi when there is no flow of flushing water through the unit, and reset it if necessary. If this condition persists, remove the pressure regulator, then reinstall it about 10 feet farther "upstream." The tubing connection in the bonnet of the regulator is a bleed-off line that allows the regulator to bleed itself should foreign matter, or a worn seat, permit seepage through the regulator; otherwise, pressure to the valve would build up slowly and exceed the highest pressure rating.

MAINTENANCE AND REPAIR

The washer should be inspected at regular intervals to ensure that it works properly. If an

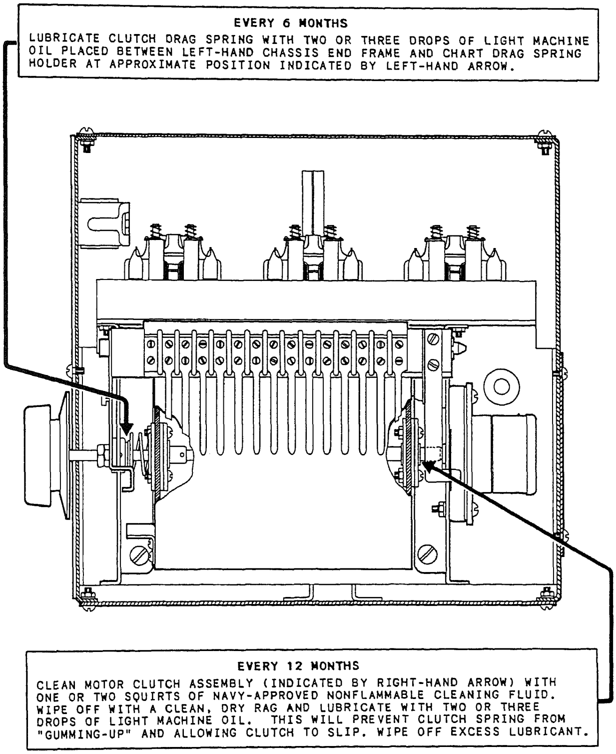
inspection reveals adjustments or repairs are needed, they should be made promptly. Some of the important items to be covered in an inspection are as follows:

1. Ensure the machine is level.
2. See that all bolts, nuts, and screws are tight.
3. See that latches on cylinder doors work properly.
4. Make sure the thermometers are accurate.
5. Check switches to ensure they are properly adjusted and working correctly.
6. Ensure timers are in good working order.
7. Check water level gauges to determine if they are correct.
8. See that all electric controls are working.

Every 2 months, check the gearbox oil level and replenish it with fresh oil, if necessary.

Drain the gearbox and replenish it with fresh oil once per year. The drain plug in the bottom of the gearbox has a small magnet in its end to attract metallic particles in the oil. Be sure to clean off the magnet each time the gearbox is drained and before reinserting the drain plug.

Every 6 months, lubricate the clutch drag spring with two or three drops of light machine oil between the left-hand chassis end frame and the chart drag spring holder, at the approximate position indicated by the left-hand arrow in the chart shown in figure 12-3.



Courtesy of Pellerin-Milnor Corporation

54.351

Figure 12-3.—Lubrication and cleaning points on Miltrol timer.

Every 12 months, clean the motor clutch assembly (indicated by a right-hand arrow in the chart) with one or two squirts of Navy-approved nonflammable cleaning fluid. Wipe it off with a clean, dry rag and lubricate with two or three drops of light machine oil to prevent the clutch spring from "gumming up" and allowing the clutch to slip. Wipe off excess lubricant.

TROUBLESHOOTING

The washer is a rugged machine, but from time to time you can expect trouble. The information below will aid you in finding the source of various troubles in Milnor washers.

POWER FAILURE:

A complete power failure causes all electrical components to stop. A partial power failure, however, affects only certain parts of the machine and is usually caused by a broken wire or defective switch. With the aid of a simple voltmeter or test light and the wiring diagram contained in the Miltrol, you can learn exactly where the voltage is lost. Start probing at the point of power input, terminals one and two in the rear of the Miltrol, and work toward the portion of the Miltrol circuit where the mechanisms are not working. If the washer basket turns but nothing else in the Miltrol operates, the voltage loss may be at the power transformer in the Miltrol. See if there is voltage on the primary side but none on the secondary side.

DRAIN VALVE FAILURE CHECK-LIST—DRAIN FAILS TO CLOSE (AIR-OR WATER-OPERATED DRAIN VALVES):

1. Master switch turned OFF.
2. Drain switch at OPEN.
3. Drain finger not touching the timer cylinder screen or touching it at a dirty or greasy spot.
4. The interior light is not lit—the drain relay may not be working.
5. The drain relay is working but the contacts are dirty.
6. The pilot solenoid valve is not operating—place your hand on top of it to feel the motion inside. You may have no voltage here, or the valve piston may be stuck.
7. Low air or water pressure to operate the drain valve which requires a minimum of 25 pounds of pressure. The pressure regulator USES WATER TO OPERATE THE DRAIN VALVE; IT IS ABSOLUTELY NECESSARY TO OBTAIN WATER FOR THIS PURPOSE AHEAD OF ALL WATER INLET VALVES IN THE PLANT.
8. Piston cup needs replacing.

DRAIN VALVE FAILURE CHECK-LIST—DRAIN FAILS TO OPEN:

1. Clogged exhaust line from the pilot valve to the soap chute. Every time the drain switch is opened, air or water should emit from the exhaust line into the soap chute.
2. Rusted or broken spring in the drain valve itself.
3. Dented drain valve cylinder.
4. Faulty pressure regulator allowing water or air over 40 psi to enter the pilot solenoid drain valve.

WATER VALVE FAILURE CHECK-LIST—WATER VALVE FAILS TO OPEN:

1. Master switch turned OFF.
2. Appropriate water switch turned OFF.
3. Water finger not touching the timer cylinder screen or touching it at a dirty or greasy spot.
4. Drain valve is open. It is impossible to admit water into the washer with the drain valve open.
5. Valve is not operating electrically because of a broken wire in the leads that go to the inlet valves, or shorted coil in the water valve.
6. Pilot orifice in the inlet is clogged with foreign matter.
7. Buildup of lime or similar deposit causing the inlet valve piston to bind.
8. Excessive water pressure (often seen in plants using steam to heat water in "instantaneous" water heaters).
9. Water level control is not operating because the float is binding in the chamber. The float chamber may be coated with soap residue, lint, or lime deposit.
10. Switches inside the level control are not operating—either they are faulty or are not being depressed. Move the float rod to its extreme positions to see if the switches click.
11. Extremely low water pressure.
12. Dirty strainers in the water inlet line.

WATER VALVE FAILURE CHECK-LIST—WATER VALVE FAILS TO CLOSE; WASHER OVERFLOWS:

1. Short or ground in the water valve coil. Turn power OFF to close the valve.
2. Water pressure is extremely low.
3. Piston return spring in the valve is broken.
4. Piston or the pilot orifice in the piston is clogged by foreign matter.
5. Pilot orifice seat in the water valve piston eroded or prevented from shutting off fully by foreign matter (also causes valve to leak).
6. Clogged float chamber in the level control.
7. Cracked or faulty float in the level control.
8. High and low level adjusting collars on the float rod are set too close together.

TIMER CYLINDER DOES NOT TURN:

1. Master switch not at FORMULA.
2. Water level not attained. Timer stops until the selected level is reached.
3. Improper switch position for Zero Level Starching. For Zero Level Starching on Model E Miltrols, the master switch must be at FORMULA and the drain switch at SHUT.
4. A loose setscrew on the clutch that joins the timer motor shaft to the time cylinder. (Consult the manufacturer's instruction manual.)
5. No voltage at the timer motor. Skin the insulation back slightly on each motor lead to check the voltage. Be certain to tape the skinned wire when finished.
6. If you must replace the timer cylinder motor, replace BOTH THE MOTOR AND GEAR CASE, NOT JUST THE MOTOR ALONE.

WASHER CYLINDER RUNS BUT NO PART OF AUTOMATIC CONTROLS FUNCTIONS:

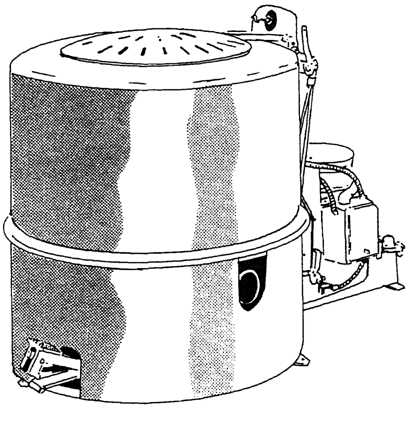
1. Defective transformer.
2. If the signals operate, the drain relay is faulty, or the drain finger does not contact the timer cylinder screen.
3. Drain switch at OPEN.

MILTROL OPERATES BUT DOES NOT RUN—OR RUNS IN ONE DIRECTION:

1. Faulty reversing control timer motor.
2. Reversing control contactor coil burned out.
3. Faulty microswitch on reversing control cam mechanism.
4. Low voltage.
5. Broken wire.
6. Signal relay contacts dirty, or faulty signal relay.

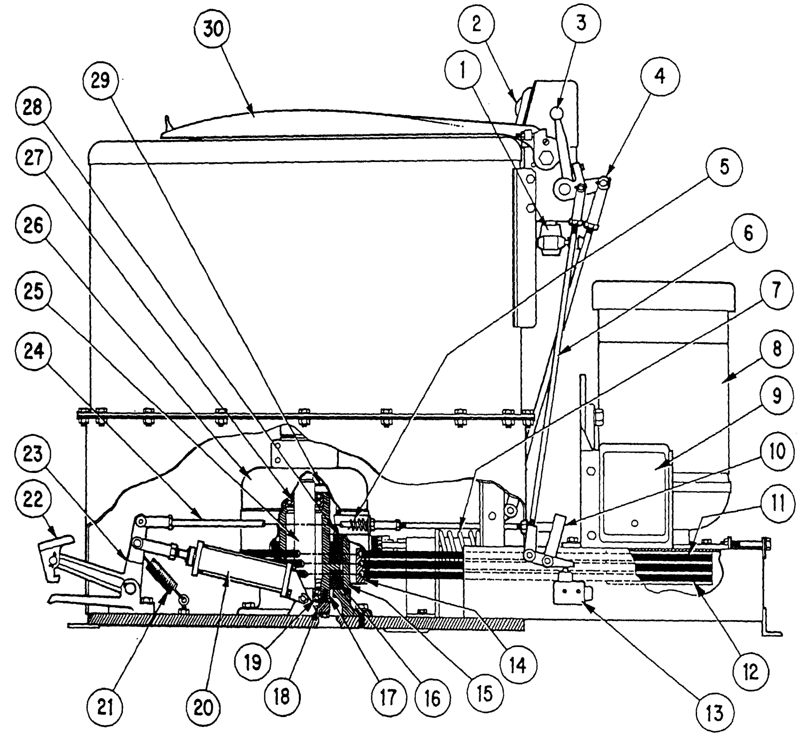
EXTRACTOR

The purpose of the extractor is to extract water from clothes after rinsing. Water is extracted by spinning the clothes at a high speed, applying centrifugal force, pushing the water to the outer surface, and discharging it through small holes in the basket of the extractor to drain. Figure 12-4 shows a Milnor extractor you may often see in use at Navy activities. Milnor extractors are available in three models: GSM-4-20, GSM-3-26, and GSM-3-30. These extractors may be equipped with a manual brake or an automatic brake. An



22.14

Figure 12-4.—Extractor.



LEGEND:

1. SOLENOID VALVE
2. TIMER (25 Minutes)
3. OPERATING LEVER
4. INTERLOCK CLEVIS ROD
5. BRAKE PRESSURE SPRING
6. SWITCH LEVER ROD
7. INTERLOCK RETURN SPRING
8. MOTOR
9. MAGNETIC STARTER
10. BELL CRANK
11. 3" "V" BELTS
12. MOTOR PULLEY
13. MICROSWITCH
14. BRAKE PULLEY
15. PEDESTAL
16. RUBBER MOUNTING
17. BEARING HOUSING
18. BOTTOM BEARING CAP
19. LOWER BEARING
20. AIR CYLINDER
21. BRAKE RETURN SPRING
22. BRAKE PEDAL
23. BRAKE LEVER BRACKET
24. BRAKE ROD
25. SPINDLE
26. BRAKE
27. UPPER BEARING
28. PACKING NUT
29. RUBBER WATER BARRIER
30. COVER

Courtesy of Pellerin-Milnor Corporation

54.352

Figure 12-5.—Assembly drawing of Milnor stainless steel extractor.

assembly drawing of a Milnor stainless steel extractor is shown in figure 12-5.

INSTALLATION

The procedure for installing extractors varies with different makes and models. The instructions given here apply to the Milnor extractor, Models GSM-4-20, GSM-3-26, and GSM-3-30. These machines may be installed on any good floor or foundation, and they operate without excessive vibration if properly leveled and bolted down.

When installing the extractor on a concrete floor, carefully lower the machine over the foundation bolts, taking care that the threads of the foundation bolts are not damaged. Support the extractor by the base and side rails so the three bolt-down pads and rear bolt-down angle are about 1 inch above the foundation. Lightly grease the three hold-down bolt pads and rear angle to permit the machine to be jacked up off the grout pads without damaging the grout. CAREFULLY AND THOROUGHLY WORK THE GROUT UNDER THE HOLD-DOWN PADS AND REAR ANGLE TO ENSURE 100-PERCENT CONTACT BETWEEN THE GROUT AND THE HOLD-DOWN PADS AND THE GROUT AND THE REAR ANGLE. (See fig. 12-6.) Do not embed pads or angles to grout. Use a non-shrinking grout, such as Stone Hard, Embecco, Pourock or equivalent. Make the grout pads about 6 inches square under each of the three hold-down pads, and in the rear of the machine, extend the pad about 2 inches past the edge of the angle in all four directions. When the grout is completely cured, jack up the machine and remove the supports under the machine. Carefully lower the machine onto the grout and securely tighten all foundation bolts. DO NOT GROUT UNDER THE BASE. No part of the round base or the motor rails should touch the floor or any of the bolts that may protrude below the base. If any part of the base or motor rails come in contact with the floor, this could cause the extractor to vibrate excessively. Make sure the extractor is reasonably level.

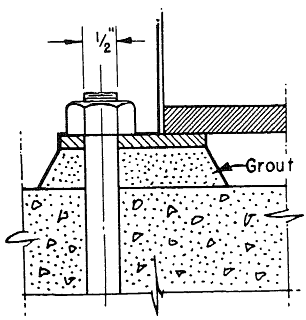


Figure 12-6.—Grout.

Check the voltage shown on the nameplate for proper electrical specifications.

The 26- by 36-inch extractors with an automatic brake require air pressure to operate the brake air cylinder. Connect the air supply to the 1/4-inch strainer inlet located at the rear of the machine just below the cover interlock box. Adjust the needle valve to prevent the brake pedal from slamming when it is applied automatically by the air cylinder.

The automatic brake on the 20-inch extractor is electrically operated and does not require air pressure.

The extractor may be drained from either the right-hand or the left-hand side. Be careful in connecting the drainpipe to make sure the stainless steel coupling is not torn out of the bottom of the extractor. If a rigid connection to the drain is used, the extractor must be bolted down and must not be allowed to vibrate. It is best to use a short piece of flexible hose in the drain line near the extractor; otherwise, vibration might cause the drain coupling to be cracked out of the bottom of the extractor.

Have a Construction Electrician connect your motor to the power supply. An extractor motor draws high current for a long time during starting. It is, therefore, necessary to use much larger wire and line fuses than for average motor applications. The machine should be wired and fused by following the recommendation on the tag attached to the machine. While you may find local peculiarities, the recommendations will suffice in most cases. A fused line disconnect switch should be installed, but this switch is not provided by the manufacturer.

Be sure the rotation of the basket is in a clockwise direction, as shown on the nameplate.

The extractor should be thoroughly grounded through the grounding lug provided on the motor. Have the Construction Electrician run a ground wire from the lug to a steam or water pipe in your plant.

After installation, thoroughly clean the inside of the basket to remove the dust and grime that have accumulated during shipment.

MAINTENANCE AND REPAIR

If the extractor is to give satisfactory service for a long period of time, it should be properly maintained and repaired promptly. Information on the maintenance and upkeep of the Milnor extractor is furnished below.

The extractor rubbers should be checked at regular intervals to ensure they are in good condition. When necessary, the rubbers should be tightened or replaced. To tighten the rubbers, simply remove the packing lock and turn the packing nut clockwise with a spanner wrench provided by the manufacturer.

To replace the extractor rubbers, remove the curb assembly. Now, remove the basket from the spindle. The basket is held to the spindle with a locknut on the inside of the basket, and the shaft and basket are fitted together with a taper. The basket may be removed from the spindle by "jolting" it off of the spindle or, if the extractor has been in service for a long period of time, you may have to press the basket off of the spindle. Next, remove the pulley, loosen the packing nut, and remove the bearing housing assembly with its shaft and bearings, after which new rubbers may be installed and the extractor assembled in reverse order. When installing new rubbers, be sure to place the flat face of the rubbers so they face the flange on the bearing housing; this will ensure that the concave side of the rubbers are down on the lower rubber and up on the upper rubber.

Ensure the extractor is lubricated at all points recommended by the manufacturer. Also, use lubricants approved by the manufacturer. As for the frequency, lubricate every 30 days or as experience dictates. Note that shaft bearings are packed at the factory and do not require greasing.

TROUBLESHOOTING

In troubleshooting the extractor, you must be able to recognize common troubles, and know the possible causes of the trouble. Obviously, a lot of time may often be saved if the cause is found before any corrective action is started. The information below will be useful to you as a guide in finding the sources of troubles in Milnor extractors.

MOTOR FAILS TO START (all 20-inch models and 26- and 30-inch manual brake machines):

1. Check for power failure.
2. Check for blown line fuses.
3. Overload relay tripped. Wait 5 minutes, then push the reset button on the magnetic starter.
4. Loose connection in wiring.
5. Microswitch in the aluminum switch box is not actuating properly. Check linkage to cover the interlock level and the manual foot brake (if applicable).

MOTOR FAILS TO START (26- AND 30-inch automatic brake machines):

1. Interlock switch faulty, or not being actuated by the bell crank.
2. Piston cup in brake air cylinder binding, preventing free motion of the piston.
3. Brake locked "VN" manually.

MOTOR RUNS BUT MACHINE FAILS TO COME UP TO SPEED:

1. Load not properly balanced.
2. Low voltage and/or frequency.
3. Loose connection in switch or wiring.
4. One fuse blown (three-phase).
5. Dirty or worn brushes on commutator (single-phase).
6. Interlock or brake shoes dragging.
7. Clothes or other material inside the curb, jamming the basket.
8. Belts loose and slipping.
9. Brake not releasing when extractor is turned on.

MOTOR RUNS BUT OVERHEATS:

NOTE: You should not become alarmed if the motor becomes too hot to touch. An electric motor is rated for operation with a given temperature rise (usually 40 °C to 50 °C) above room temperature. Thus, when the room temperature is around 100 °F, as is normal in laundry and dry-cleaning plants, a motor rated with a 50° rise may operate at 190 °F without affecting its life. The average person cannot keep his/her hands on an object hotter than about 125 °F; therefore, it is easily seen that a motor can get "too hot to handle" without being overheated.

1. It is probably normal.

2. Too many stops and starts per hour, or not enough running time for each load. The motor on the extractor is designed for a maximum of eight starts per hour, and a minimum running time of 6 minutes per load. The maximum of eight starts per hour includes false starts; that is, when it is necessary to stop the machine and rebalance the load. This limitation is necessary to allow the motor to cool after each start.

3. Excessively low voltage—caused by an overloaded line condition, or low voltage supplied by the power company.

BRAKE NOT RELEASING WHEN THE EXTRACTOR IS TURNED ON (20-inch extractor):

1. Solenoid plunger rod or other portion of the brake mechanism is binding. Solenoid plunger must be completely free.
2. Low voltage or frequency.
3. Too much tension on the brake pressure spring.
4. Loose connection in the solenoid wiring.

BRAKE NOT RELEASING WHEN THE EXTRACTOR IS TURNED ON (26-inch and 30-inch extractors):

1. Exhaust port of pilot solenoid valve is clogged.
2. Bad microswitch in timer box.
3. Pilot solenoid valve jammed open.

EXTRACTOR MAKES KNOCKING NOISE WHEN RUNNING:

1. Machine not properly bolted to the floor. Feel with your hand around the edge of the base for vibration and movement.
2. Packing nut loose.
3. Spindle pulley loose on the spindle. Tighten by means of two draw-down bolts in the hub of the spindle pulley. Be careful not to tighten it too much.
4. Rubbers worn.
5. Basket loose on spindle. Tighten basket nut.
6. Bad bearings. This is unusual. Bad bearings may be identified by heavy whirring and/or rumbling noise similar to the noise made by ball-bearing roller skates. Also check motor bearings.
7. Motor pulley loose on the shaft.

EXTRACTOR FAILS TO CARRY NORMAL OUT-OF-BALANCE LOAD:

1. Rubbers too loose or too tight.
2. Motor not developing full power.
3. Brake not fully releasing when the motor is turned on.
4. Extractor not fully bolted down to the floor.

TUMBLER

For satisfactory ironing or wearing of clothing and various other articles, the extractor leaves too much moisture in these materials. The machine used in Navy laundries to remove the moisture from different materials to ensure good ironing is called the tumbler—or drying tumbler.

One type of tumbler commonly used at Navy activities is the Huebsch Loadmaster model 42-inch tumbler. This is a commercial type of tumbler with a drying capacity of 100 pounds (dry weight) of laundry per hour. A two-motor drive system provides independent fan and cylinder operation. A one-way cylinder rotation and a door safety switch are standard. The instructions below on the installation, maintenance, and repair of tumblers apply to the Huebsch Loadmaster model 42-inch tumbler.

INSTALLATION

When installing the tumbler, make sure it is level and properly secured to the floor. In leveling, use shims of adequate size to avoid weight concentration.

The dryer room must be well ventilated. An opening of 2 square feet to the atmosphere must be supplied for each 1,700-cubic-feet per minute (cfm) model and 4 square feet for each 3,000-cfm model. Allow adequate clearance on all sides for servicing and efficient loading and dispatching of dried materials. Do not overlook a clearance for future ductwork if it might be needed.

Steam Connections

On steam-heated laundry tumblers, steam coils are guaranteed to 125-psi working pressure. A minimum of 100 psi should be maintained for efficient performance on laundry tumblers. Connect 3/4-inch steam supply and return lines to the coils as marked on the coil housing. The inlet is at the top, the discharge at the bottom.

Pitch the steam lines for proper draining. Install flexible steam hoses between coils and piping to reduce strain on the coils. Supply each coil bank with shutoff valves at the inlet and outlet connections. Locate the steam trap at least 1 foot below the discharge level of the coil. Install a strainer between the steam coil and the trap. Install a swing check valve after the trap. Use valves and unions to isolate the steam trap, strainer, and check valve for ease of replacement or repair. A trap for each coil is recommended for best performance.

Electrical Connections

Laundry tumblers are factory-wired for operation and require only power supply connection. Refer to the wiring diagram in the control box lid and connect three-phase service to posts L-1, L-2, and L-3 in the control box. A fused disconnect should be installed. For multiple-tumbler installations, each unit should be equipped with a disconnect switch. Information for fuse size can be found inside the control box cover. Fan and cylinder motors have thermal overload circuit breakers mounted in the control box. Super tumblers have a cylinder motor fuse block in the control box. Have a Construction Electrician make this connection. Check fan rotation.

Ductwork

For maximum efficiency of single- or multiple-unit installation, air discharge must be ducted individually to the atmosphere by the shortest possible route. Avoid sharp turns. Use sweep elbows for 90° turns. The duct size must equal the discharge spout or be larger for runs less than 20 feet. For each additional 30 feet of duct run, increase the entire duct diameter by one-tenth for round duct or the entire duct area by one-fifth for rectangle duct. A single 90° elbow is equal to adding 16 feet of 12-inch-diameter duct run or 21 feet of 16-inch-diameter duct run, and the entire duct diameter should be refigured accordingly. For multiple-unit installations where a common header is absolutely necessary, feeder ducts must enter a 45° angle in the direction of airflow. Header size must increase progressively at each duct entry to allow for full airflow capacity of all the units. Discharge to the atmosphere must be constructed to get rid of too much back pressure and to prevent the entrance of weather. Use 180°-sweep elbows of ample size for vertical runs and 90°-sweep elbows for horizontal runs. No caps, screens, or bags should be installed on the end of the discharge duct. The end of the duct should be at least one diameter away from any obstacle.

Testing

Before placing the tumbler in service and with the power off, check for correct cylinder, belt, and chain adjustment as described later in this chapter. Turn the power on and start the tumbler to check the cylinder and fan rotation and the door switch adjustment. On standard units, the cylinder must rotate clockwise when viewed from the front of the tumbler. The fan must always turn clockwise when viewed from inside the lint drawer housing. Turn the steam on. Place a load of damp rags in the cylinder and run until dry. Check the cylinder adjustment under load and check for vibration or unusual noise. Reversing models must be checked for correct time delay between reversing cycles. Correct any adjustment before placing the tumbler in service.

MAINTENANCE AND REPAIR

Try to keep the tumblers operating at peak efficiency. Some of the general maintenance and minor repair procedures in the care and upkeep of tumblers are explained below.

Electrical Control Box

Loose wire connections can cause tumbler failure and possible damage. Remove the control box cover and check the controls monthly. Replace the contactor points when pitted or worn. Check and tighten all wire connections, including thermal overload heating coils. Check for secure mounting of controls to the control box. Failure of holding coils, thermal overload circuit breakers, or any part of the reversing timer assembly requires replacement. (For detailed information, consult the manufacturer's electrical parts booklet.)

Electric Motors

Ensure that electric motors are removed and cleaned thoroughly at least once a year. All motor repairs should be performed by the Construction Electrician. Frequent tripping of the thermal overload circuit breakers may be caused by low voltage, loose connections, reversed fan, or high ambient temperature. Never increase

thermal overload heater size without complete investigation.

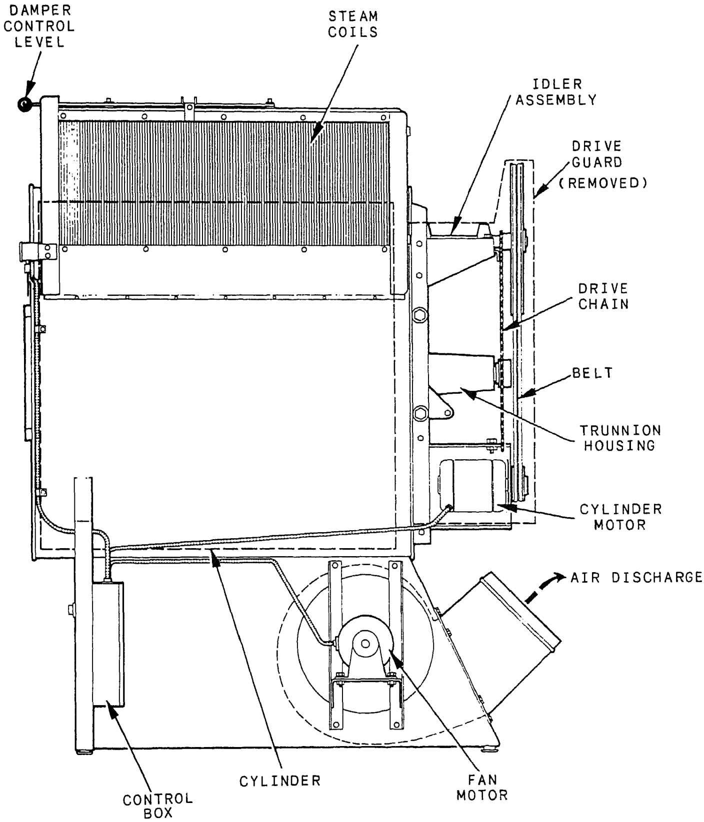
Electrical Safety Controls

The door switch, thermostat, and other optional electrical equipment require replacement upon failure. Shut off the power and observe all details of the mounting and wiring. Mark the wire before removal. After exchange, check the wiring diagram before turning on the power. Check with the power on. Adjust if necessary before returning to service.

Adjustments

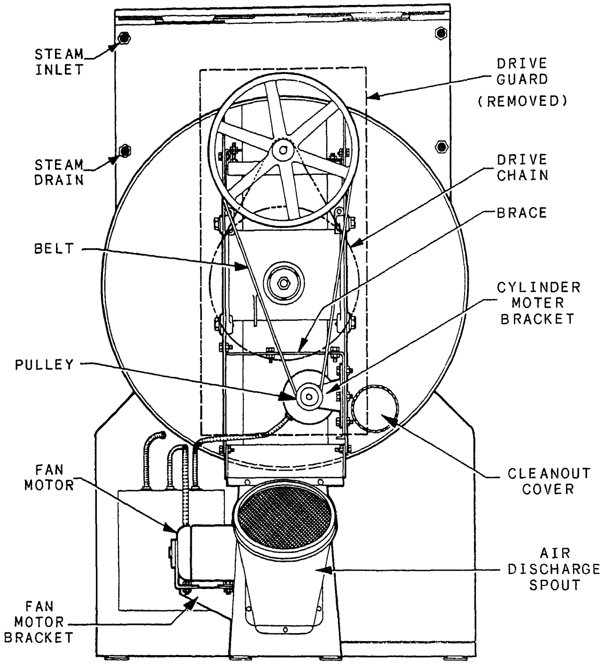
In servicing the tumbler, you may have to adjust the belt, chain, cylinder, and reversing timer (on machines so equipped), and door safety switch at various times. To make these adjustments, follow the procedures below.

BELT.—To increase belt tension, loosen the four bolts holding the cylinder motor to the bracket and force the motor evenly downward. (See figs. 12-7 and 12-8.) Tighten the



54.354

Figure 12-7.—Right side view of tumbler.



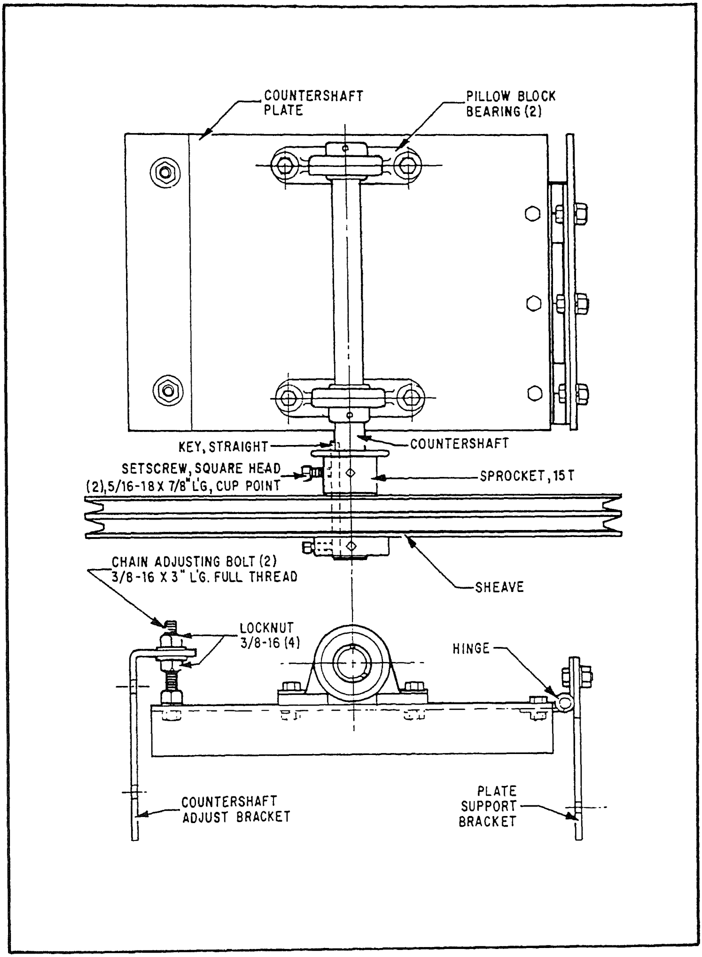
54.355

Figure 12-8.—Rear view of tumbler.

bolts and check the alignment with the belts and large sheave, using a square or small level. Check for belt tension midway between the motor pulley and the large sheave. Adjust to 1-inch travel under slight thumb pressure. Check the chain adjustment at the same time.

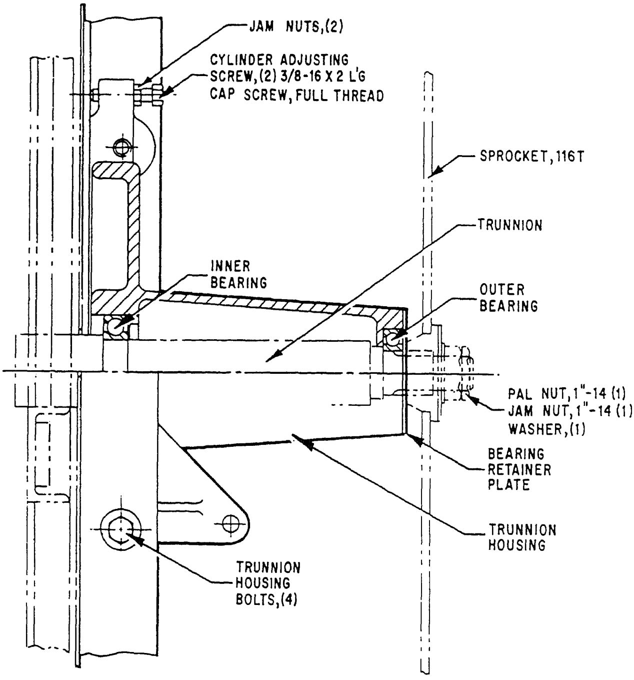
CHAIN.—This adjustment is controlled through the upward and downward movement of the hinged idler adjusting plate. (See figs. 12-7, 12-8, and 12-9.) The two adjusting screws attached to the adjusting plate are locked to the adjusting screw support bracket with locknuts on both sides of the plate. At this point, all chain adjustments are made. To tighten the chain, loosen the locknuts on top of the support bracket several turns, and tighten the bottom locknuts evenly. A good chain adjustment is never banjo tight. Check the chain midway between the large and small sprockets for 1-inch free travel. Set your adjustment at this point and tighten both adjusting screw locknuts. To loosen the chain, turn the bottom locknuts downward, always evenly. Retighten the top locknuts when the adjustment is correct. Check the belt adjustment at the same time.

CYLINDER.—In adjusting the cylinder, remove the two tapered pins securing the trunnion housing to the rear support angles. Do not reuse these pins which are for shipping only. Loosen the four bolts holding the



54.356

Figure 12-9.—Idler assembly.



54.357

Figure 12-10.—Trunnion housing assembly.

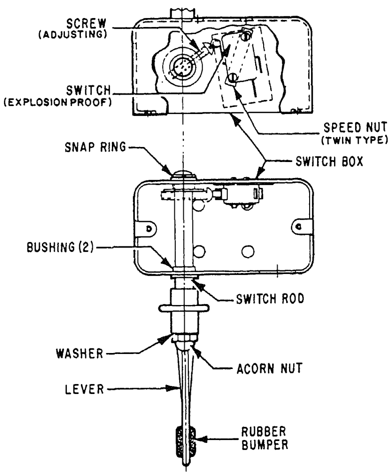
trunnion housing to the angles. (See figs. 12-7, 12-8, and 12-10.) Loosen the locknuts on the two adjusting screws at the upper corners of the trunnion housing. Turning the screws clockwise raises the cylinder, turning counter-clockwise lowers the cylinder. Adjust until the distance between the cylinder and loading door flange is equal at all points or slightly greater at the bottom to allow for the weight of the load. Tighten the adjusting screw locknuts and trunnion housing bolts securely. Recheck the adjustment before turning to service.

REVERSING TIMER.—On tumblers equipped with a reversing cylinder, check the cylinder rotation with a normal load to ensure complete stoppage of the cylinder between reversing cycles. To increase the time delay, pull out the back dial in the center of the timer assembly and rotate it clockwise one-eighth of an inch. The dial is under spring tension and returns to the engaged position when correctly in line. Check the cylinder with the power on and repeat for more delay. Turn counterclockwise to reduce time delay. Never advance more than one notch without checking the cylinder. Power must always be off when the timer dial is being rotated manually.

DOOR SAFETY SWITCH.—The door safety switch assembly is preset at the factory to stop the cylinder when the door is opened approximately 6 inches. Repair or replacement may make readjustment necessary. (See figs. 12-8 and 12-11.) To adjust, loosen the nut on the bottom of the switch shaft and loosen the switch lever from the serrated end of the shaft. Rotate the lever toward or away from the tumbler to decrease or increase the door adjustment to the 6-inch operating point. Retighten the lever and nut.

Lubrication

Once a month, remove the circular cover on the drive guard and oil the chain, using SAE-30 oil. The pillow block, trunnion, and motor bearings are sealed and require no service.



54.358

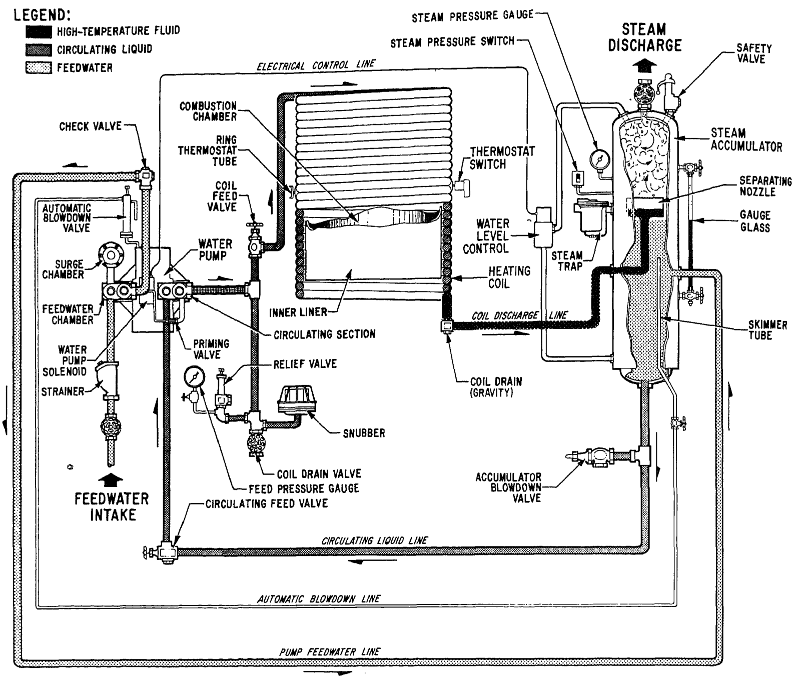
Figure 12-11.—Door safety switch assembly.

STEAM GENERATOR

The purpose of the steam generator is to provide enough steam to operate both tumblers, as well as to provide a continuous supply of hot water to both washers under constant operation. One type of steam generator frequently used in laundries at Navy activities is the Clayton steam generator, Model RO-33-PL, which is discussed in the paragraphs below.

The Clayton steam generator is a watertube boiler that delivers its rated output of 99 percent quality steam (containing less than 1 percent moisture) per hour from 60°F feedwater. The generator develops its full-rated pressure within 5 minutes from a cold start.

The generator features a continuous circulating feedwater system with a constant capacity pump that ensures a wet tube in the generator heating unit at all times. Automatic controls regulate the feedwater rate and modulate or stop the burner by steam demand. Standard equipment includes safety devices for protection against water failure, burner failure, too much pressure, and electrical overload.



54.359

Figure 12-12.—Flow diagram of a generator's water and steam circuit.

A flow diagram of the water and steam circuit of the generator is shown in figure 12-12. Supply water enters the feedwater section of the water pump from the hot well/feedwater tank and is pumped directly to the steam accumulator. The circulating liquid is drawn from the accumulator by the circulating section of the water pump and pumped into the single-passage heating coil, and then back to the accumulator where the steam is separated.

The pump is driven directly by an electric motor and contains no packing boxes. It is arranged in two sections: the feedwater section and the circulating section. The pump diaphragms are operated hydraulically by oil displaced by reciprocating pistons within the pump. A built-in solenoid-operated bypass valve is on the hydraulic pressure section of the feedwater pump to prevent the feedwater section from pumping when the valve is open. The valve is actuated by the water level control according to the liquid level in the accumulator.

INSTALLATION

When installing the boiler, pay attention to the fuel, water, electrical, and venting facilities. Ample clearance should be allowed on all sides to make operation and maintenance easier.

Use shims, if necessary, to prevent distortion of the frame when drawing-down foundation bolts.

When installing external piping, use pipe unions next to the boiler connections to allow easy removal of parts for inspection and cleaning.

Fuel Requirements

The boiler is equipped to burn No. 2 diesel fuel oil. Make connections as follows:

Connect the fuel supply line to the inlet connection on the fuel filter. If the fuel supply tank is located above the fuel pump, install a shutoff valve in the supply line at the filter inlet. If the fuel tank is below the fuel pump (maximum lift 10 feet), use three-eighths of an inch diameter pipe (minimum) with a check or foot valve installed in the supply tank. In this case, install a swing check valve at the fuel filter instead of a shutoff valve to ensure against loss of prime. Frictional losses on long runs of pipe reduce the 10-foot maximum suction lift of the fuel pump previously mentioned.

Note the fuel suction line must be an individual line from the fuel tank, and all air leaks and air pockets must be repaired to avoid erratic burner operation.

Connect the return line to the return connection below the fuel pump. The return line must be a separate line back to the fuel tank and NOT connected to the fuel suction line to prevent locking of air in the fuel system, which would cause erratic burner operation.

CAUTION: Do not install a shutoff valve in the return line. A swing check valve may be installed if the fuel pump is below the fuel tank. IMMEDIATE DAMAGE to the fuel system results if the return line is closed.

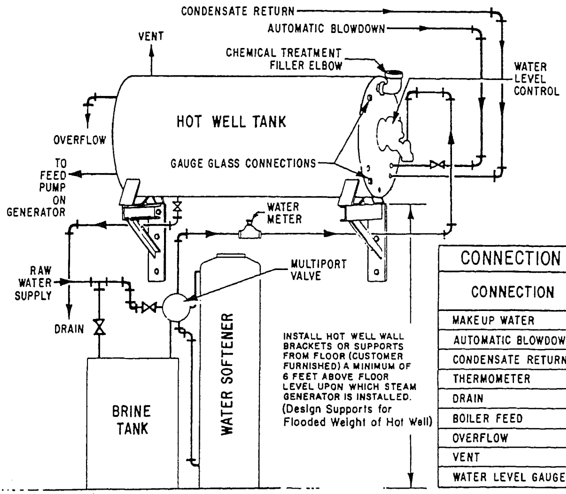
Venting Requirements

Install a stack adapter (supplied with the steam generator) directly on the heater cover stack outlet. Install a stack extension if desired, using 12-inch-diameter flue pipe (minimum), and install a weather cap (supplied with the unit) at the top of the flue pipe.

If the unit is operated in an enclosed building, extend the flue pipe through the roof and install a weather cap. For a horizontal run, a minimum pitch of 15 degrees from the horizontal must be maintained. Increase the diameter of the flue pipe 2 inches of each 10 feet of horizontal run. Also increase the diameter proportionately when more than one or a series of sharp bends are necessary.

Hot Well/Feedwater Tank

Typical hot-well installation and connection data are shown in figure 12-13. The hot well must



CONNECTION DATA

CONNECTION	PIPE SIZE
MAKEUP WATER	3/4"
AUTOMATIC BLOWDOWN	1/2"
CONDENSATE RETURN	1-1/4"
THERMOMETER	1/2"
DRAIN	1"
BOILER FEED	1-1/2"
OVERFLOW	1-1/2"
VENT	1-1/2"
WATER LEVEL GAUGE	1/2"

54.360

Figure 12-13.—A typical installation of horizontal hot-well tank and connection data.

be elevated on a suitable stand or bracket to allow a 60-inch gravity feed to the inlet of the feedwater pump check valve housing for hot-well temperatures up to 180°F. If higher hot-well temperatures are anticipated, a higher gravity feed is required to prevent vapor locking of the feedwater pump. For hot-well temperatures of 180°F to 200°F, a 72-inch gravity feed is necessary. Temperatures above 200°F require a gravity feed of 84 inches.

Feedwater Connections

The feedwater connection is made by connecting a line between the feed pump connection on the hot well and the feedwater intake valve by using a minimum of 1-inch-diameter pipe.

Steam, Blowoff, and Drain Connections

The steam header should be connected to the steam discharge valve. See that the header pipe size is not smaller than the steam discharge valve. A valve bleed line to the atmosphere should be installed at the steam discharge. This allows releasing steam to permit the steam generator to operate under full load when adjustments are made.

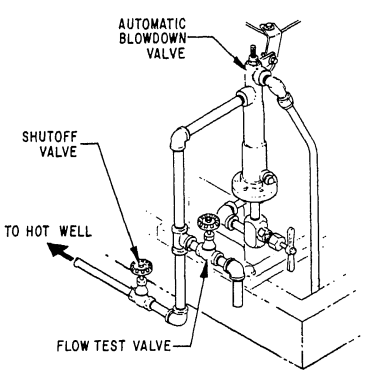
Connect the pipe accumulator blowdown valve and coil drain valve to waste. These lines may be manifolded into a common line of not less than 1-inch-diameter pipe.

Connect the pipe discharge from the steam safety valve to the atmosphere. You should provide a 1/4-inch-diameter (minimum) pipe drain at the lowest point in the safety valve vent line piping.

The pipe outlet from the accumulator steam trap should be connected to the condensate return connection on the hot well with 3/4-inch-diameter pipe.

Automatic Blowdown Valve

To permit periodic checking of the automatic blowdown valve adjustment, install a shutoff valve and a flow test valve, as shown in figure 12-14. Pipe the discharge from the shutoff valve to the automatic blowdown connection on the hot well.



54.361

Figure 12-14.—Suggested automatic blowdown valve discharge piping.

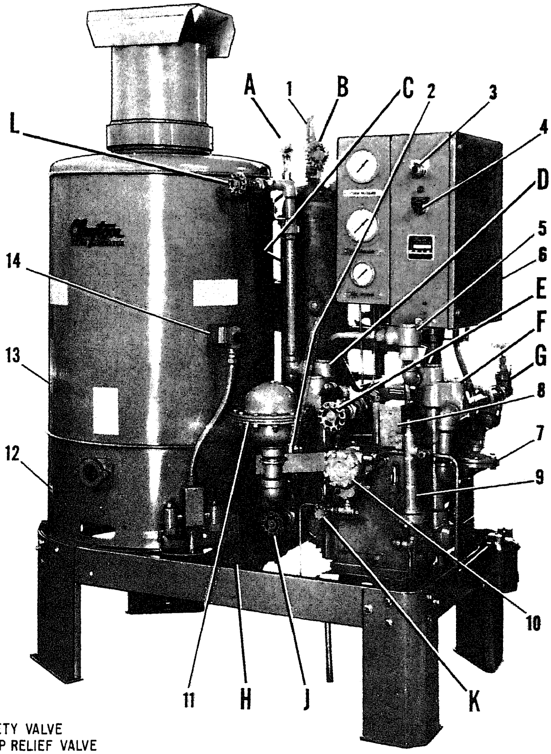
Electrical Connections

Make electrical connections to terminals in the electrical control box. Install a disconnect switch in the line next to the steam generator to ease the isolation of electrical components from the line if service is necessary. Start the motor momentarily to check rotation. Rotation should be clockwise as viewed from the front of the plant.

PREVENTIVE MAINTENANCE AND REPAIR

Like any piece of mechanical equipment, the steam generator requires proper maintenance and some repairs will be needed to maintain the efficiency and service it is designed to render. The following discussion covers some of the maintenance requirements and repair procedures for the Clayton steam generator, Model RO-33-PL. For detailed information on the maintenance and upkeep of this and other types of generators, consult the manufacturer's instruction manual.

Before proceeding, observe that figure 12-15 shows the operating controls and parts as seen



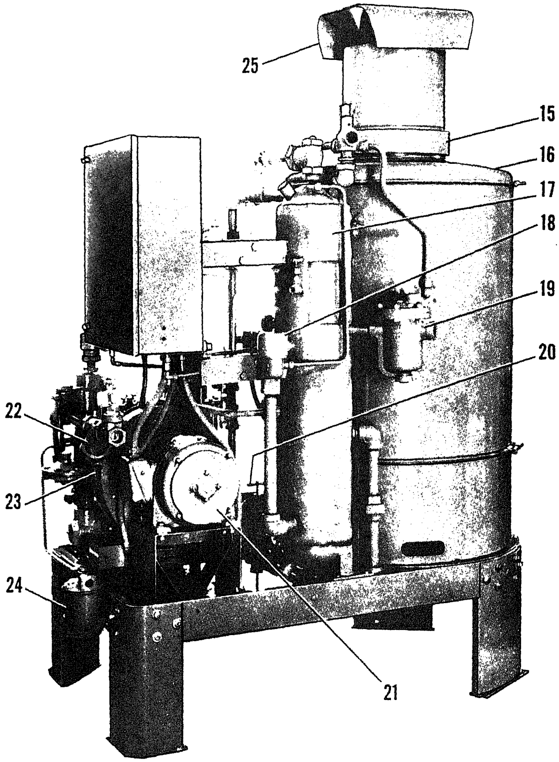
1. STEAM SAFETY VALVE
2. WATER PUMP RELIEF VALVE
3. START-STOP SWITCH
4. EMERGENCY RUN SWITCH
5. CHECK VALVE
6. ELECTRICAL CONTROLS BOX
7. INTAKE SURGE CHAMBER
8. WATER PUMP SOLENOID
9. AUTOMATIC BLOWDOWN VALVE
10. FUEL PUMP
11. WATER PUMP DISCHARGE SNUBBER
12. BURNER BASE
13. HEATING UNIT
14. THERMOSTAT SWITCH

A. SOOT BLOWER VALVE
B. STEAM DISCHARGE VALVE
C. ACCUMULATOR GAUGE GLASS
D. CIRCULATING PUMP HOUSING
E. CIRCULATING FEED VALVE
F. FEEDWATER PUMP HOUSING
G. FEEDWATER INTAKE VALVE
H. ACCUMULATOR BLOWDOWN VALVE
J. COIL DRAIN VALVE
K. BURNER CONTROL VALVE
L. COIL FEED VALVE

54.362.1

Figure 12-15.—Operating controls and component identification of Clayton steam generator, Model RO-33-PL, front view.

15. STACK ADAPTER
16. HEATER COVER
17. STEAM ACCUMULATOR
18. WATER LEVEL ELECTRODE HOUSING
19. STEAM TRAP
20. AUTOMATIC BLOWDOWN SHUTOFF VALVE
21. MOTOR
22. FEEDWATER STRAINER
23. BLOWER INSPECTION COVER
24. FUEL FILTER
25. WEATHER CAP



54.362.2

Figure 12-16.—Operating controls and component identification of Clayton steam generator, Model RO-33-PL, rear view.

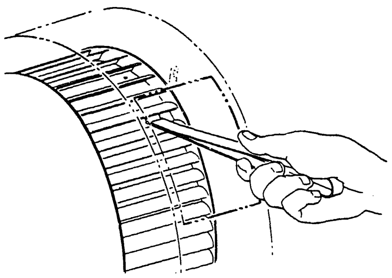
from the front of the generator, and figure 12-16 shows the operating controls and parts as viewed from the rear. The letters and numbers shown in parentheses in the sections that follow refer to those used to identify the name and location of operating controls and parts in figures 12-15 and 12-16.

Cleaning the Blower

If dirt or lint accumulates on the cupped sides of the blower rotor blades, a shortage of air to the burner causes reduced burner efficiency. The frequency of cleaning depends on the amount of dirt or lint in the air at the installation. To clean, unscrew the wing nut and remove the blower inspection cover (23). As figure 12-17 shows, insert the curved end of the cleaning tool under the rotor blade and move the tool back and forth until the entire undersurface of the blade is cleaned. Repeat this operation on all blades.

Thermostat Control Test

Check the operation of the thermostat control every 100 operating hours. Study the



54.363
Figure 12-17.—Using the blower rotor cleaning tool.

complete test procedure below and then follow the steps in rapid succession.

With the plant operating at normal pressure (burner on), close the feedwater intake valve (G) and circulating feed valve (E).

With the burner still on, open the coil drain valve (J) and accumulator blowdown valve (H). Now start a 60-second maximum time check. Remember that the 60-second maximum timing of the burner shutoff starts the INSTANT that the coil drain valve and accumulator blowdown valve are opened.

Progressively close the steam discharge valve (B), so steam pressure does not rise to maximum but is maintained about 5 to 10 psi below the steam pressure switch cutout point to permit continuous burner operation without cutoff by the steam pressure switch. After the discharge valve is fully closed, do not reopen it until the time check is complete.

When the thermostat is in correct adjustment, the burner shuts down within 60 seconds after the accumulator blowdown and coil drain valve (H and J) are opened.

CAUTION: If the burner fails to shut down within 60 seconds (maximum), shut off the fire immediately and adjust the thermostat for proper control. The procedures for adjusting the thermostat switch and the thermostat ring channel are given later in this chapter.

After the burner shuts down, open the burner control valve. Close the accumulator blowdown and coil drain valves (H and J).

Open the feedwater intake valve (G) and the circulating feed valve (E). Allow the plant to fill with water, and prime the circulating pump if necessary. To resume operation, start the burner when the plant is filled.

Checking for Coil Restriction

When a water pump is noisy, the trouble is sometimes due to a restricted heating coil that causes excessive feed pressure. The feed pressure should be checked for coil restriction. When checking for coil restriction, compare the reading on the feed pressure gauge with that on the steam pressure gauge. Normal feed pressure may vary slightly with each installation. Carefully note the pressure right after the steam generator is installed, so an accurate check of coil restriction can be made for the unit. Always note the feed pressure after the steam generator has operated for a while and thoroughly heated and always at the same operating steam pressure. Steam pressure must be maintained at least 25 to 30 psi below the maximum under steady load to prevent burner modulation. To check the feed pressure, open the valve to the feed pressure gauge just enough to allow a steady reading on the gauge. The coil is restricted if feed pressure is 30 pounds or more above the normal feed pressure noted immediately after installation or when the coil was completely clean. For example, if feed pressure was 250 psi at a given steam pressure when the unit was new, remove scale from the heating coil when this pressure rises to 280 psi.

Blowdown Operation

To blowdown the system, follow this procedure:

With the plant operating at normal steam pressure, close the circulating feed valve (E) and open the coil drain valve (J). Start a time check.

After 30 seconds, shut off the burner and close the steam discharge valve (B).

NOTE: If the burner is shut down by the thermostat control during the time check, immediately open the burner control valve (K); then close the steam discharge valve.

Open the accumulator blowdown valve (H).

When the steam pressure drops to zero, close the coil drain valve (J) and the accumulator blowdown valve (H).

Open the circulating feed valve (E).

To resume operation, allow the plant to fill with water and start the burner in the normal manner. You may have to reprime the circulating pump after the blowdown.

Priming Pumps

To prime the feedwater pump, open the sample valve on the side of the housing until the air is expelled. If the pump fails to prime, loosen the intake valve cap two turns to get rid of the air, then retighten it. Be careful when loosening this cap as it has the pressure of water from the hot well against it.

Prime the circulating pump in a similar manner as for the feedwater pump. Be sure the circulating pump is primed by slowly closing the coil feed valve (L) and observing the feed pressure gauge. If the pump is primed, feed pressure will rise when the valve is nearly closed. As a positive check, continue to close the valve until the pump relief valve (2) begins to discharge. The circulating pump is not fully primed if the relief valve cannot be made to discharge. Fully open the coil feed valve after the positive check is completed. In priming the pump, do not loosen the cap on the intake valve of the circulating pump if any pressure is on the boiler. The cap should be under the same pressure as the boiler.

Lubrication

When the electric motor is equipped with sealed bearings, the bearings are prelubricated for the life of the bearings. Motors equipped with oil wick lubricated bearings should be given 1 teaspoon of good grade oil into the reservoirs every 6 months. Too much oil does as much harm as not enough. Too much oil will allow seepage into the motor and is revealed by too much oil around the motor shaft. If the motor is equipped with pressure grease fittings, remove the plug below the motor shaft every 6 months and force a light grade of grease into the port at the top until the clean grease appears at the plug outlet. To prevent rupture of the grease seals, run the motor for 4 or 5 minutes before replacing the plug below the motor shaft.

Every year (more often under severe operation), drain and refill the water pump crankcase with a good grade of SAE 20 motor oil (about 5 quarts required). With the pump running, oil should show at least halfway in the sight gauge.

Water Pump Check Valves

When the check valves of the water pump are not operating properly, you may have to inspect and clean the valves. The valves should also be inspected and cleaned when you remove scale from a restricted heating coil.

In this discussion on check valves, refer to the drawing of a water pump in figure 12-18 as we go along. This illustration has been labeled to show the name and location of different parts of the water pump, and the numbers shown in parentheses in the text refer to those shown in figure 12-18.

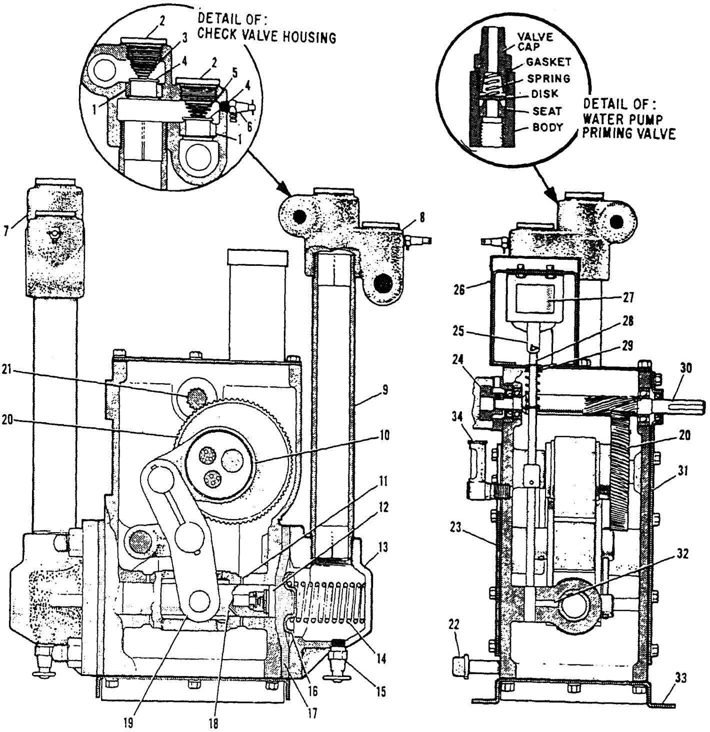
When inspecting the check valves, unscrew the valve caps (2) from the housing (7 and 8) and disassemble the disks (4) from the caps. Remove scale and pits from the disks by rubbing them in a "figure 8" motion on a piece of fine sandpaper (wet or dry No. 400 or finer) placed on plate glass. The disks must be perfectly smooth and flat for proper water pump operation.

Inspect the springs (3 and 5) for distortion and free length. The free length of discharge springs (3) should be 1 1/32 inch; the free length of intake springs (5) should be 25/32 inch. Replace any broken or distorted springs.

When assembling, make sure you first assemble the spring to the disk by placing a finger inside the spring at the center and pressing the small end of the spring over the button on the disk; then attach the spring to the valve cap. In this way, the spring does not get distorted or deformed. Remove and process the check valves one at a time to avoid interchanging parts.

Inspect the valve seats (1) to see if they are scored or damaged. Seat faces must be narrow and perfectly flat. Replace damaged seats, following instructions given in the section below.

Scale may be removed from the inside of the check valve housing by filling the housing and pump columns with a solution of two parts water and one part of a Navy-approved scale-removing acid. Scale on springs and disks may be removed by immersing them in the same solution. After



1. Valve Seat
2. Valve Cap
3. Discharge Spring
4. Valve Disk
5. Intake Spring
6. Bleeder Cock
7. Circulating Housing
8. Feedwater Housing
9. Pipe Column
10. Connecting Link
11. Oil Port
12. Hydraulic Chamber
13. Pump Head
14. Spring
15. Drain Cock
16. Diaphragm Cup
17. Diaphragm
18. Piston
19. Rocker Arm
20. Main Gear
21. Pinion Gear
22. Drain Cap
23. Front Cover
24. Fuel Pump Coupling
25. Solenoid Armature
26. Solenoid Housing
27. Solenoid
28. Bypass Rod
29. Packing
30. Drive Shaft
31. Rear Cover
32. Bypass Port
33. Base
34. Oil Level Gauge

54.364

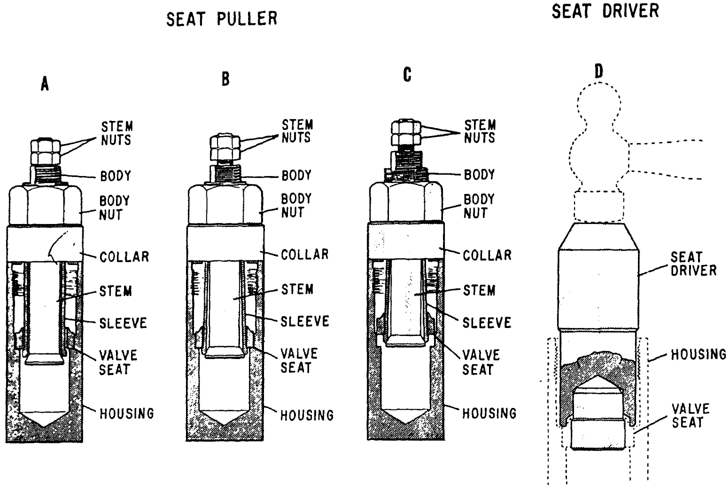
Figure 12-18.—Water pump.

the scale has been dissolved, thoroughly flush the parts with water. Open the drain cocks (15) to flush the pump columns.

Replacing Water Pump Seats

To replace the valve seats in the water pump, use a special seat puller and a special seat-driving tool. Using these tools, proceed as follows:

Adjust the seat puller so the wedge at the lower part of the stem is free of the sleeve, and unscrew the body nut enough to allow the shoulder on the sleeve to extend below the valve seat when the



54.365

Figure 12-19.—Use of special seat puller and seat driver.

puller is inserted into the check valve housing. (See view A, fig. 12-19.)

Insert the puller in the check valve housing and turn the stem counterclockwise with the stem nuts until the shoulder on the sleeve is securely wedged below the bottom of the valve seat, as shown in view B.

Hold the body with the wrench and turn the body nut clockwise until the valve seat is free of the check valve housing, as shown in view C. Remove the seat puller and turn the stem clockwise to free the seat.

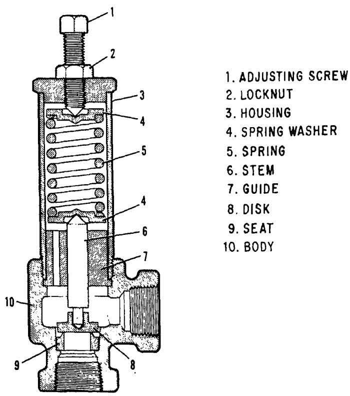
Drive the new seat with the seat-driving tool, view D, but be careful not to damage the seat face.

Water Pump Relief Valves

The relief valve of the water pump should be adjusted to open at about 500-psi feed pressure but remain driptight during operation. Leakage from this valve results in a lack of water to the heating unit and causes overheating.

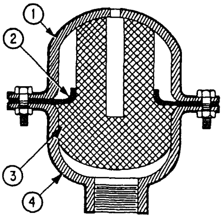
You will find that under certain conditions, when starting the unit, feed pressure may temporarily rise enough to cause the relief valve to release a small amount of water. Feed pressure will return to normal, however, after the unit heats and the system becomes stabilized.

A drawing of a pump relief valve is shown in figure 12-20. In the following instructions on the adjustment and repair of the relief valve, the numbers in parentheses refer to those used in the figure.



47.120(54F)

Figure 12-20.—Pump relief valve.



54.366

Figure 12-21.—Water pump discharge snubber.

To adjust the relief valve, proceed as follows: Start the plant without the burner in operation and slowly close the coil feed valve, L of figure 12-15, until the relief valve just begins to discharge; check the pressure on the feed pressure gauge at that point.

To raise the pressure adjustment, turn the adjusting screw (1) clockwise; to lower the pressure adjustment, turn the screw counter-clockwise. Secure the adjusting screw with the locknut (2) after the adjustment.

Fully open the coil feed valve. Inspect the valve for leakage during normal operation.

To repair the relief valve, use the following procedures:

Loosen the adjusting screw (1) and unscrew the housing (3) from the body (10). Inspect the disk (8) and seat (9) for scoring or other damage. Replace the seat if damaged.

If the disk is scored, it may be resurfaced by rubbing it on a piece of fine sandpaper (wet or dry No. 400 or finer) placed on a perfectly flat surface.

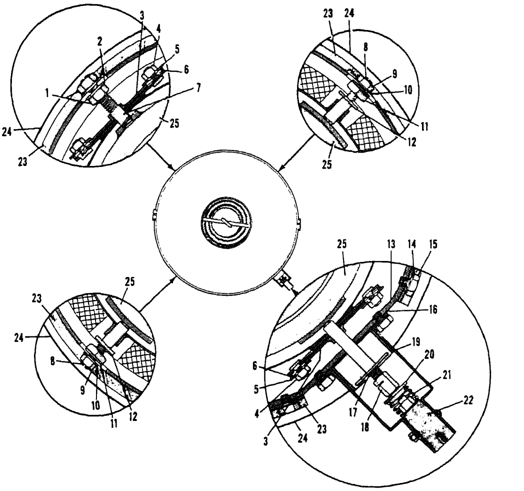
Reassemble the valve, making sure the spring washers (4) are not cocked in the housing.

Water Pump Discharge Snubber

The water pump discharge snubber (fig. 12-21) is nonadjustable. If the rubber insert has to be replaced, the old insert must be cut away from the retainer. To ease assembly, lubricate the new insert with glycerine (do not use oil) to allow it to be pushed into the retainer and bottom housing.

Ring Thermostat Control

To keep the ring thermostat control of the generator (fig. 12-22) at peak operation, you may



54.367

Figure 12-22.—Ring thermostat control.

have to adjust the thermostat switch and the thermostat ring channel. In making these adjustments, follow the procedures below. The numbers in parentheses refer to those used in figure 12-22.

THERMOSTAT SWITCH ADJUSTMENT.— The plant must be operated long enough to be thoroughly heated before you adjust the thermostat switch.

Remove the cover from the thermostat switch (22) to expose the adjusting nut (18).

With the plant operating, adjust the steam discharge so steam pressure is maintained just below the steam pressure switch cutout point. This step provides maximum steam temperature and prevents burner cutoff by the steam pressure switch during adjustment.

Slowly turn the thermostat adjusting nut (18) out until it actuates the thermostat switch to cut off the burner; then turn the nut back in about a three-quarter turn. This should allow the burner to start again.

Test the thermostat as instructed earlier in the section entitled "Thermostat Control Test." A slight readjustment of the thermostat adjusting nut may be necessary to obtain correct safety shutdown of the burner.

THERMOSTAT RING CHANNEL ADJUSTMENT.—Adjust the thermostat ring channel (23) when replacing the heating coil or if the original assembly has been disturbed. A careful check of the adjustment must also be made if the thermostat switch cannot be adjusted without erratic response.

In adjusting the thermostat ring channel, be sure the guide plates (3) are tightly secured to the flanges at the front and rear of the coil. Also be sure the tie strap (13) is tightly secured to the ring channel (23).

Loosen the locknuts (1) and securely tighten the anchor stud (7) into the boss at the rear of the ring thermostat tube (25).

With the channel adjusting screws (8) loosened so the channel (23) is free to move, adjust the locknut (1) at the rear of the channel to where the clearance between the channel and the coil insulation is about equal at the front and rear. Do not completely tighten the locknuts.

Adjust the channel adjusting screws (8) to where the clearance between the channel and the coil insulation is about equal at the sides. Take up all lateral play against the pre-load buttons (12) without too much pressure against the buttons.

Check the alignment of the adjusting stud holes in the tie strap (13) and the front guide plate (3). You may need to rotate the ring channel to bring these openings into alignment. After alignment is complete, tightly secure the locknuts (1) at the rear of the channel.

Again adjust the channel adjusting screws (8) so they center the ring channel in relation to the coil insulation and bear against the pre-load buttons just enough to take up the play. Then turn each adjusting screw in one-half to one turn more to create a proper pre-load on the channel; then secure with locknuts (9). Adjusting screws should be positioned nearly at the center of the pre-load buttons.

Check the clearance between the ring channel and the coil insulation. One-sixteenth of an inch (minimum) should be allowed at all points around the insulation. Also be sure that clearance (1/16-inch minimum) is allowed between the ring channel and the outer shell (24) when the outer shell is secured in the burner base.

Install the adjusting stud (17), adjusting nut (18), bracket (19), washer (20), spring (21), and switch (22). Make the thermostat switch adjustment as instructed above.

Automatic Damper

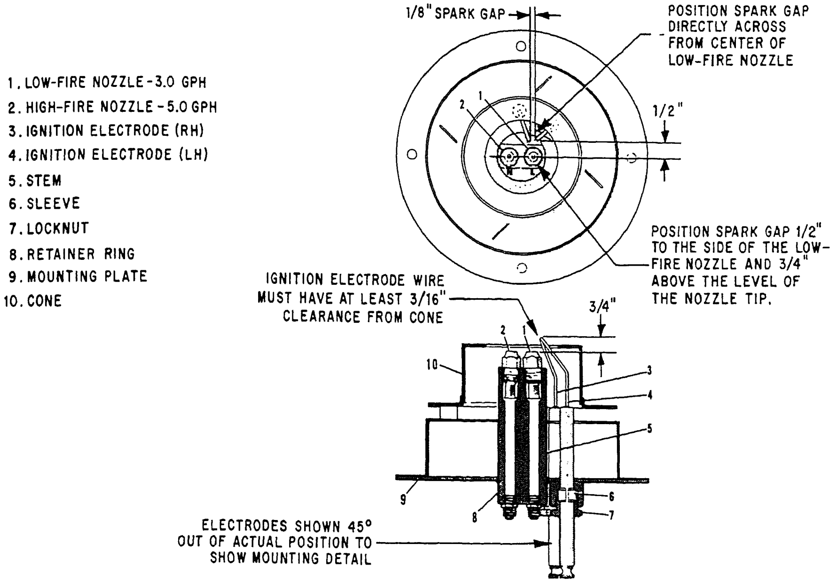
The automatic damper should be kept in proper adjustment to ensure a proper supply of air to the burner.

When the air supply is to be adjusted for HIGH-FIRE burner operation, the following procedure applies: With the plant operating, regulate steam discharge to keep the steam pressure at least 25 psi below maximum to ensure full burner operation. Loosen the wing nut on the high-fire adjusting screw and turn the adjusting screw clockwise until smoke is noticed at the stack outlet; then turn the screw counterclockwise until the smoke disappears. The burner works best by adjusting the air just to the point of smoke elimination.

When the air supply is to be adjusted for LOW-FIRE burner operation, operate the plant at near maximum steam pressure (between 5 and 10 psi below maximum). The low-fire adjustment is made in the same manner as the high-fire adjustment except that the low-fire adjusting screw is turned counterclockwise until the smoke appears at the stack outlet, then turned clockwise until the smoke disappears.

Burner Manifold

The burner manifold (fig. 12-23) requires cleaning and adjusting at times to keep it in good



54.368

Figure 12-23.—Burner manifold.

shape. The procedure for cleaning and adjusting the manifold is as follows:

Disconnect the fuel lines and remove the cables from the burner manifold. Unscrew the nuts that attach the manifold to the burner and remove the manifold. Scrape carbon deposits from the manifold and ignition electrodes.

Unscrew the burner nozzles from the stem. Unscrew the strainer from the nozzle and remove the screw. Blow parts out with a compressed air jet if available. Be sure all dirt and grit are removed.

CAUTION: In cleaning, do not use a sharp instrument that can scratch or disfigure the tip orifice or slots in the distributor. A slight scratch on these parts can seriously impair nozzle operation.

Adjust ignition electrodes to conform with dimensions given in figure 12-23. The gap must be positioned as accurately as possible so it is at the immediate edge of the nozzle spray. Because of slight differences in individual nozzle spray angles, try to position the gap somewhat nearer or farther from the nozzle than shown. If points are placed too far into the spray, fuel striking the electrodes causes fuel drip from the burner. If the gap is too far away, erratic ignition or ignition failure results. The electrodes may be raised, lowered, or rotated by loosening the locknuts attaching them to the mounting plate.

Be careful when bending and adjusting the electrodes to avoid cracking the insulators. The insulators may develop an invisible short due to such a fracture, resulting in ignition failure.

Fuel Pressure Regulator

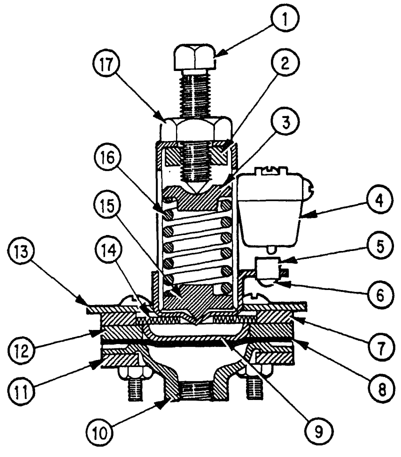
The fuel pressure to the burner must be properly maintained. Excessive fuel pressure causes the burner to smoke and results in sooting of the heating coil. However, if fuel pressure is

too low, the plant comes up to pressure slowly and does not maintain adequate steam pressure during periods of maximum steam demand. Normal fuel pressure ranges between 40 to 160 psi, depending upon the type and gravity of fuel used. Avoid raising fuel pressure to where the generator is overfired, causing thermostat interruption. To adjust the fuel pressure, operate the burner at full fire and remove the cap nut from the lower right-hand side of the fuel pump. Insert a screwdriver and turn the adjusting screw clockwise to increase pressure, counterclockwise to decrease pressure.

Fuel Pressure Switch

Figure 12-24 shows a drawing of a fuel pressure switch. To adjust the switch, follow the procedure below.

Adjust the switch to close the light and fuel indicator pilot when fuel pressure rises to about 70 psi by turning the adjusting screw (1) (fig. 12-24) clockwise to increase or counterclockwise to decrease pressure at which the switch closes. This step allows enough pressure to induce proper atomization when fuel is admitted to the burner. Secure the adjusting screw with the locknut after adjustment.



LEGEND:

1. ADJUSTING SCREW
2. NUT PLATE
3. SPRING WASHER
4. SWITCH
5. LEAF SPRING
6. SPRING GUIDE
7. GUIDE RING
8. DIAPHRAGM
9. DIAPHRAGM WASHER
10. BASE
11. RING
12. GUIDE RING
13. COVER
14. WASHER
15. PIVOT WASHER
16. SPRING
17. LOCKNUT

54.369

Figure 12-24.—Fuel pressure switch.

Steam Pressure Switch

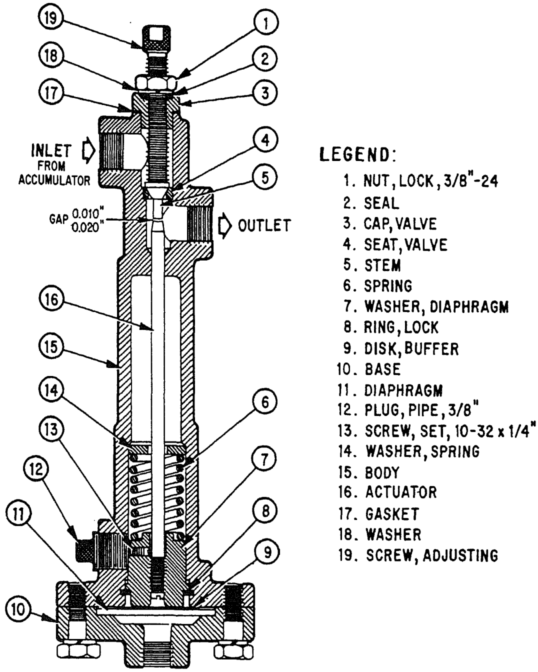
The steam pressure switch (SPS) can be adjusted to open and stop the burner at any maximum pressure between 65 and 195 psi. The switch closes and restarts the burner when steam pressure drops about 8 psi below that point. To adjust, turn the large slotted screw at the top of the switch until the dial pointer on the switch is opposite the maximum pressure desired. The dial is approximate and final adjustment should be made by using the steam pressure gauge as a standard. If the steam pressure switch setting is changed, the modulating pressure switch should also be readjusted.

Modulating Pressure Switch

The modulating pressure switch (MPS) is normally adjusted to modulate the burner to "low-fire" operation when steam pressure reaches 10 psi below maximum and to return the burner to "high-fire" operation when steam pressure drops about 8 psi below that point. This adjustment can be raised or lowered in relation to maximum steam pressure but should never be set closer than 5 psi below the steam pressure switch cutout point. When it is set too close to the maximum steam pressure, operation is unstable and tends to "override" during an abrupt drop in steam load. When set too low, steam pressure is not maintained at high level during heavy loads. The recommended setting of 10 psi below the maximum, in most cases, provides both stable operation and stable steam pressure during fluctuating demand. To adjust, turn the large slotted screw at the top of the switch until the dial pointer on the switch is opposite the pressure desired. As with the steam pressure switch, the dial setting is approximate and the steam pressure gauge should be used for final adjustment.

Automatic Blowdown Valve

The automatic blowdown valve is operated by oil pressure from the water pump. If the



54.370

Figure 12-25.—Automatic blowdown valve.

blowdown valve diaphragm gets ruptured, oil will likely appear in the waste discharge. Replace a ruptured diaphragm immediately to prevent the loss of oil from the pump crankcase. Figure 12-25 shows a drawing of a blowdown valve and its various parts. In this discussion on the blowdown valve, note that the numbers in parentheses refer to those in the figure.

As preventive maintenance, replace the blowdown valve diaphragm whenever the water pump diaphragms are replaced. Since wear may affect the operation of the blowdown valve, dissemble the valve each time the diaphragm is replaced and internal valve adjustments checked by using the following instructions:

Disconnect the tubing and bracket from the blowdown valve. Unscrew the blowdown valve from the water pump. Disassemble the base (10) from the body (15) and remove the diaphragm (11) and the buffer disks (9) from the body.

Loosen the locknut (1) and turn the adjusting screw (19) in until it holds the valve stem (5) firmly against the valve seat (4).

Using a feeler gauge through the outlet port, check the gap between the valve stem (5) and the actuator (16). The gap should be 0.010 inch (minimum) to 0.020 inch (maximum).

To adjust, remove the pipe plug (12) and loosen the setscrew (13). Insert a screwdriver into the slot in the bottom of the actuator for the proper gap. Secure the actuator with a setscrew when proper adjustment is made.

Assemble the two buffer disks (9), diaphragm (11), and base (10) to the body (15) and secure

with cap screws. Recheck to determine if the gap established earlier still exists.

Screw the blowdown valve into the water pump and secure the bracket with cap screws and hex nuts. Attach the tubing and adjust the valve for correct capacity, as specified in the manufacturer's instruction manual.

TROUBLESHOOTING CHARTS

A troubleshooting chart for the Clayton steam generator, Model RO-33-PL, is shown in table 12-1. This chart will guide you in finding and correcting troubles in that make and model of generator. You will find similar charts in the

Table 12-1.—Troubleshooting Chart for Clayton Steam Generator, Model RO-33-PL

WATER SYSTEM.

Trouble	Possible Cause	Remedy
FEEDWATER PUMP FAILING TO MAINTAIN PROPER WATER LEVEL IN ACCUMULATOR GAUGE GLASS.	Accumulator blowdown valve open or leaking.	Inspect accumulator blowdown valve.
	Feedwater pump not primed.	Prime pump.
	Insufficient water to feedwater pump.	Check water supply to pump. Be sure intake valve is open.
	Feedwater strainer clogged.	Clean strainer.
	Feedwater pump check valves not operating properly.	Clean and inspect check valves.
	Water pump solenoid not releasing.	Remove water level electrodes and clean off rust and dirt.
		Check water pump solenoid armature and linkage for binding.
CIRCULATING PUMP FAILING TO MAINTAIN PROPER FEED VOLUME TO HEATING COIL, CAUSING THERMOSTAT INTERRUPTION.	Low oil level in water pump causing reduced pump capacity.	Be sure oil is maintained at proper level.
	Priming valve not operating properly.	Clean and inspect priming valve.
	Circulating pump check valves not operating properly.	Clean and inspect check valves.
	Vaporlock of circulating pump due to abrupt steam demand causing low pressure in accumulator.	On installations where there are sudden heavy steam demands, a back pressure valve should be installed to retain a normal steam pressure in the accumulator during these periods.
	Circulating pump not primed.	Prime circulating pump.
TOO MUCH WATER. (Unit operating with high water level in gauge glass.)	Water pump solenoid not operating.	Check for burned out solenoid coil or open circuit to solenoid.
		Remove and clean water level electrodes. Corrosion on electrodes may cause insulating effect and prevent operation of solenoid.

WATER SYSTEM.—Continued.

Trouble	Possible Cause	Remedy
TOO MUCH WATER—Continued.	Water pump solenoid not operating.	Check for defective water level relay.
	Steam trap plugged.	Remove and clean steam trap.
NOISY WATER PUMP OPERATION.	Flexible coupling loose between motor and pump.	Tighten setscrews in flexible coupling.
	Pump intake surge chamber fouled.	Check and clean intake surge chamber.
	Restricting heating coil causing excessive feed pressure.	Check feed pressure for coil restriction.
WATER PUMP CYCLES RAPIDLY.	Leads to water level electrodes reversed.	Check wiring to electrodes (see wiring diagram.)

FUEL SYSTEM.

Trouble	Possible Cause	Remedy
LOW OR NO FUEL PRESSURE. Caution: Stop plant immediately to avoid damage to the fuel pump.	Fuel supply exhausted or supply lines restricted.	Check fuel supply. Be sure all valves in supply line are open.
	Fuel bypassing through burner control valve.	Burner control valve must be fully closed for maximum fuel pressure.
	Fuel pressure not adjusted properly.	Adjust fuel pressure.
	Air leak in supply line causing loss of prime.	Suction line must be airtight and all air pockets eliminated.
	Fuel pump failure.	Replace fuel pump.
BURNER FAILS TO IGNITE.	Faulty ignition.	Check and adjust ignition electrodes.
		Check ignition transformer and cable.
		Check for low voltage condition which may cause weak spark from transformer.
	Safety switch in combustion control locked out.	Actuate reset on control. Also check for continuity of circuit between combustion control and flame detector (under burner manifold).

FUEL SYSTEM.—Continued.

Trouble	Possible Cause	Remedy
BURNER FAILS TO IGNITE—Continued.	Fuel pressure switch failure.	Check and adjust fuel pressure switch.
	Burner nozzles not replaced in burner.	Be sure to replace nozzles after cleaning burner manifold.
	Insufficient fuel pressure.	Check causes and remedies under "Low or No Fuel Pressure."
	Oil valve failing to open.	Check for burned out solenoid.
PARTIAL OR IMPROPER BURNER OPERATION CAUSING LOW STEAM PRESSURE AT NORMAL LOAD.	Low fuel pressure.	Check causes and remedies under "Low or No Fuel Pressure."
BURNER SHUTS OFF BEFORE MAXIMUM STEAM PRESSURE IS REACHED.	Thermostat control interruption due to low water condition.	Correct cause of low water condition immediately. Test thermostat for proper control.
SMOKE FROM FLUE OUTLET. To prevent sooting of the heating coil and burner, correct this condition immediately.	Improper air supply to burner.	Check air adjustment.
	Fuel pressure not adjusted properly.	Adjust fuel pressure.
	Carboned, loose, or worn burner nozzles.	Clean and tighten burner nozzles. Replace if worn.
	Heating coil sooted.	Remove soot from heating coil.
	Dirt or sludge in fuel oil or wrong grade of fuel used.	Be sure fuel is clean and of the proper grade.
FLUTTERING BURNER SHUTS OFF DURING AUTOMATIC OPERATION.	Oil valve not seating properly.	Check and clean solenoid valve.
OIL DRIP FROM BURNER.	Oil valve not seating properly.	Check and clean solenoid valve.
	Loose burner nozzles.	Tighten nozzles.
	Carbon on burner nozzles causing deflection of oil spray.	Remove and clean nozzles.
DEAD OR FLUTTERING FIRE.	Heating coil sooted.	Remove soot.
	Improper air adjustment.	Check air adjustment.

ELECTRICAL SYSTEM.

Trouble	Possible Cause	Remedy
MOTOR FAILS TO START, OR STOPS DURING OPERATION.	Power failure or tripped circuit breaker.	Check power lines. Reset circuit breaker.
	Safety shutdown caused by overload relays.	Wait 2 or 3 minutes for overloads to cool; then press reset on magnetic controller and restart unit. Check for cause of overload.
MOTOR NOISY OR RUNNING HOT.	Motor running single phase.	Check for blown fuse or tripped circuit breaker in feeder lines.
MAGNETIC CONTROLLER FAILS TO CONTACT.	Operating coil failure.	Replace coil.

instruction manuals provided by the manufacturers of other makes of steam generators. Make sure you are familiar with the manufacturer's manual for the generator used at your activity, and follow the procedures prescribed for the maintenance and repair of the equipment.

RESIDENTIAL WASHING MACHINES

The automatic washers described in this chapter are typical of the machines on the market today. The circuits and timing diagrams are composites of the more common features found in several different models. For the equipment you are installing or working on, follow the manufacturer's instruction manual.

Many automatic clothes washing cycles can be broken down into four basic operations: fill, agitate, drain, and spin. Nearly all of these operations are repeated two or more times throughout a complete washing cycle; and for the most part, they are controlled by a timing assembly.

There are two basic methods of washing action in general use. One is a reciprocating agitator that swirls the water and clothes back and forth in a tank. The other is a rotating drum that picks up the clothes and allows them to drop into a pool or stream of water.

The fill operation is responsible for getting water into the laundry tub. The fill operation begins immediately after starting the washer, but the timer does not start until the water level is at the proper height. Some models use timed fill operations that start and end under the control of the timer of the washer. Also note that there are no timed fill operations. This type of washer uses a nontimed fill feature initiated by the timer, but terminated whenever a water level sensing switch closes. When the water level sensing switch is finally activated, the timer starts running and the agitation operation commences.

The agitation operation is the one that is responsible for washing and rinsing the laundry once the tub is filled with water. Most automatic washers intended for use are of the agitator, top-loading variety.

The drain operation pumps used wash and rinse water out of the washer and into the wastewater system.

The spin operation is responsible for removing excess water from the laundry fabrics. During this operation, the main drive motor spins the laundry tub at a relatively high rate of speed, forcing water out of the tub and laundry fabrics by means of centrifugal force. The drain pump removes this spun-out water from the washer.

Modern automatic clothes washers include a number of optional features that do not appear as necessary parts of a timing diagram. The more common options are listed below.

WATER LEVEL SELECTOR SWITCH

Most washers have a high/low selector switch; some give the user a choice of high, medium, and low water levels; and a few washers have an "infinite" water level adjustment that lets the user set the water to any desired level. The purpose of such a switch is to conserve water whenever the laundry tub is only partially filled with laundry. Some washers do not have a water level selector switch, and all wash and rinse phases run with the tub filled to capacity.

WATER TEMPERATURE SELECTOR SWITCH

In most washers you normally have access to a set of switches, push buttons, or a dial that allows a choice of water temperatures. Newer and better washers have separate selector switches for the wash water and rinse water phases; hot water, warm water, or cold water for the washing phase; and warm water or cold water for the rinsing phase. In the simplest washers, the switch might only permit a selection of either hot or cold water for both the washing and rinsing phases of the wash cycle.

AGITATION SPEED SELECTOR

The control lets you select a normal or gentle speed for the agitation action. The gentle speed is used only in instances where there is a chance that normal speed might harm certain types of fabrics. It is important to note that this speed selector switch does not influence the timing in any way. For example, if you set up a 10-minute washing operation, the operation occupies a full 10 minutes whether the agitator speed is set to normal or gentle.

THEORY OF OPERATION

An automatic washer can be an elaborate piece of electromechanical equipment. Most modern washers have a number of basic electrical and mechanical parts that work much the same way in every make and model. The main parts include a timer assembly, solenoids for controlling the inflow of hot and cold water, a transmission and main drive motor for providing the powerful agitation and spin actions, a water pump assembly for recirculating and removing water from the washer, and a host of other controls and switches.

These basic components are discussed in terms of what they do and how they do it in the paragraphs below.

Timer Assembly

The timer assembly is the "brain" of the automatic washer. The timers found in automatic washers are not much different from those found in some other major appliances, including automatic dryers and dishwashers. The cam-operated switch contacts are responsible for starting and stopping most of the basic washer operations.

The basic elements of a timing switch assembly are a split-phase motor, a set of cams, and some contact switches. The motor, usually geared down to a speed of about one-half revolution per hour, turns a set of cams that open and close banks of switch contacts. The switch contacts control the flow of line power to the various electrical devices in the washer.

Transmission Assembly

The transmission in an automatic washer is the most complex piece of mechanical machinery in the appliance industry. The transmission is wholly responsible for converting the rotary motion of the main drive motor into either an agitating motion or spinning action. Although there is often a direct linkage between the drive motor shaft and the cam assembly that produces the agitating motion, the motor is connected to the spin section of the transmission by means of a friction clutch that lets the laundry tub reach its normal spinning speed gradually without overloading the motor.

In some current models, the transmission is shifted from one type of action to another by means of a solenoid-operated gearshift. The majority, however, shift between agitate and spin according to the direction the drive motor spins. Whenever the drive motor turns in one particular direction, the transmission is shifted to the spin gear. Reversing the motor then automatically shifts the transmission to its agitate gear.

Some washing machine transmissions also have a neutral gear that allow the drive motor to turn without causing either the spin or agitation action to occur. This feature is used during drain

operations that call for running the water pump by itself.

Main Drive Motor

The main drive motor is responsible for converting electrical energy into the kind of mechanical power that is necessary for carrying out the agitation, spin, and pumping actions of the washer. The motor is normally a split-phase induction motor that is rated at about one-half horsepower. Washer motors, almost without exception, operate on 120-volt line power.

A capacitor-start feature is not necessary for washing machines using fractional horsepower drive motors, but a centrifugal switch or relay-start mechanism is always an integral part of the main drive motor's control system. In some cases, you will find that washer motors are also reversible, and they sometimes have built-in speed control windings.

Water Pump Assembly

The main purpose of the water pump is to draw used water out of the washer at the end of the washing and rinsing steps and during spin operations. The pump is also used to recirculate the wash and rinse water with the use of a lint filter. The water pump is mechanically driven by the transmission and main drive motor. It is operating whenever the main drive motor is running.

Consider now the fact that the main drive motor is reversible in most models. It runs in one direction for agitation operations and in the opposite direction for spin operations. This means the water pump runs in both directions as well; and the logical conclusion is the pump moves water in two different directions, depending on which way the main drive motor is turning.

It is possible to take advantage of this two-direction characteristic of the water pump by using it in conjunction with a two-way flapper-valve assembly. The idea is to recirculate the wash or rinse water during agitation operations and to pump the water out of the system during spin operations. By turning the drive motor and pump in the agitation direction, as shown in figure 12-26, (A) opens valve A and closes valve B. The water is thus routed through the water recirculation system inside the machine. Turning the drive motor and pump in the spin direction, as shown in figure 12-26, (B) closes valve A and opens valve B. Since valve B leads to the wastewater system, moving the water in that direction effectively drains it all out of the washer. This makes it possible to use a flapper-valve assembly for routing the water without using extra electrical controls and timer switches. Some washers control the routing of the pump water by means of solenoid valves.

Water Valves

The water valves control the inflow of hot and cold water during fill operations. The valves are

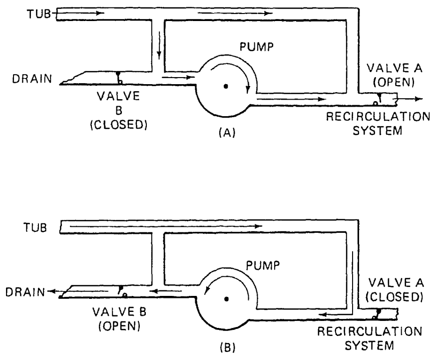


Figure 12-26.—Operation of a flapper-valve water control system: A. Pump turning in the agitate direction to recirculate the water; B. Pump turning in the spin direction to pump water out of the washer.

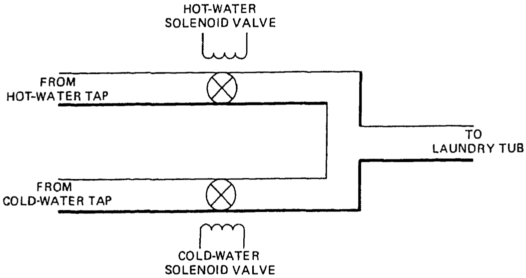
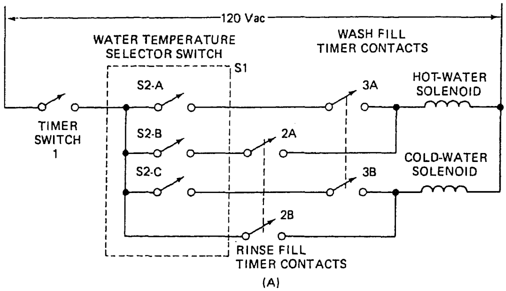


Figure 12-27.—Hot- and cold-water solenoid valve control system.



SELECTED WATER TEMPERATURE		S1 CONTACT CONFIGURATION		
WASH	RINSE	S1-A	S1-B	S1-C
HOT	WARM	X	X	0
HOT	COLD	X	0	0
WARM	WARM	X	X	X
WARM	COLD	X	0	X
COLD	WARM	0	X	X
COLD	COLD	0	0	X

X = CLOSED
0 = OPEN

(B)

Figure 12-28.—Water temperature selector circuit: A. Circuit diagram; B. Switch closures for different combinations of wash and rinse water temperatures.

electrically operated, as shown in figure 12-27. The solenoids are turned off most of the time, keeping their respective valve ports closed. The ports open only when electrical power is sent to the solenoid windings.

The two water valve solenoids can be operated individually or at the same time. Activating the "hot" valve, for instance, fills the washer with hot water. Energizing the "cold" valve fills the washer with cold water, and energizing both

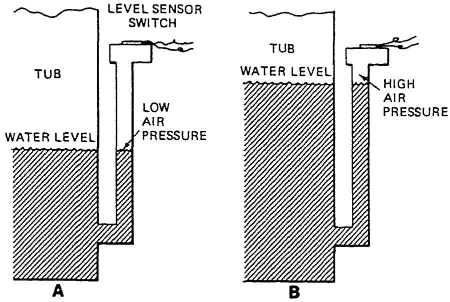


Figure 12-29.—A water level sensor scheme: A. Water level below the set point on the sensor; B. Water level at the set point.

valves at the same time fills the washer with warm water, a mixture of hot and cold.

The water temperature selector switch determines the water valves to be operated during any given fill operation; timer contacts are responsible for energizing the selected solenoids at the appropriate times.

A typical water fill circuit for modern automatic washers is shown in figure 12-28. The hot- and cold-water solenoid valves are energized through several sets of timer contacts and a water temperature selector switch assembly.

Water Level Sensing Switch

Washers that do not use a timed fill interval must have provisions for sensing the water level and turning off the water supply whenever a given water level is reached. This sensor normally takes the form of a pressure switch that is activated either directly by the water pressure on the bottom of the laundry tub, or indirectly activated by air pressure in a tube located at the rear of the washer.

The diagram in figure 12-29 shows the operation of the indirect, or air pressure, sensing mechanism. The water level in the tub is always the same as the water level in the washer. As the water level rises, the air pressure at the top of the tub increases. A pressure switch at the top of the tub can be adjusted to close at various pressure levels representing different water levels in the washer.

Door Interlock Switch

The door interlock switch is a safety feature that completely shuts down the washer whenever the door or lid is opened during a spin operation. Opening the door during any other part of the cycle does not affect the ongoing operation.

The diagram in figure 12-30 shows how the door interlock switch is bypassed by a timer contact. The timer contact is closed throughout most cycles of the washer, allowing the lid switch to be opened without interrupting current flow to the motor circuit. During every spin operation, however, the timer opens the bypass switch, letting the lid switch interrupt the complete circuit to the motor whenever the lid is opened during that particular operation.

This list of mechanical and electrical components is not complete as far as the full range of modern clothes washer models is concerned. This list is complete, however, in the sense that

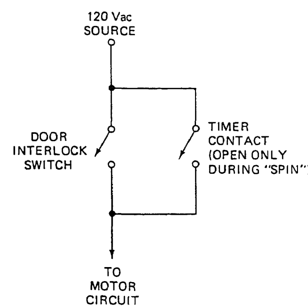


Figure 12-30.—Door switch and override circuit.

it describes the most critical components and those that are unique to clothes washers.

INSTALLATION OF WASHING MACHINES

Satisfactory performance of an automatic washing machine depends on a carefully planned and properly designed first installation. The place where the laundry is done should be well lighted and adequately equipped with convenient electrical outlets. The plumbing connections must be anchored to the floor to prevent movement. Various local code regulations apply in most communities to permanent plumbing and electrical installations.

The National Plumbing Code says the standpipe receptor for an automatic clothes washer should be installed in one of the following ways:

1. The standpipe receptor should be properly trapped and vented. The standpipe should extend no more than 48 inches or less than 18 inches above the trap. (See fig. 12-31.)
2. The standpipe receptor should be installed in the strainer plate of a floor drain provided the plate is designed to receive the standpipe. The size of the floor drain should depend on the discharge rate of the automatic clothes washer or the floor area to be drained, whichever is greater.

The NAVFACENGCOM guide specifications (TS15401) provide the following information:

Automatic Clothes Washer: Provide drainage and water piping for automatic washers as indicated. Drainage should be through a standpipe of 2-foot 10-inch minimum height from the floor. The drain line should be of galvanized steel, copper, or approved plastic, 2-inch minimum size, trapped with bottom of tray a minimum of 4 inches above the floor. The trap should be of cast iron, copper, or approved plastic. Hot- and cold-water faucets should be brass and have four-arm or lever-type metal handles, 1/2-inch male or female inlets, and 3/4-inch hose thread outlets. If appropriate, hot and cold waterlines should be provided with water hammer arresters immediately upstream of the faucets.

As you can see, local codes and military specifications vary. It depends upon where you are. In a conflict, what the ROICC (Resident Officer in Charge of Construction) says is the final word.

TROUBLESHOOTING

Now you know what the components in a washing machine do and how they do it. Use the troubleshooting chart in table 12-2 as a guide or

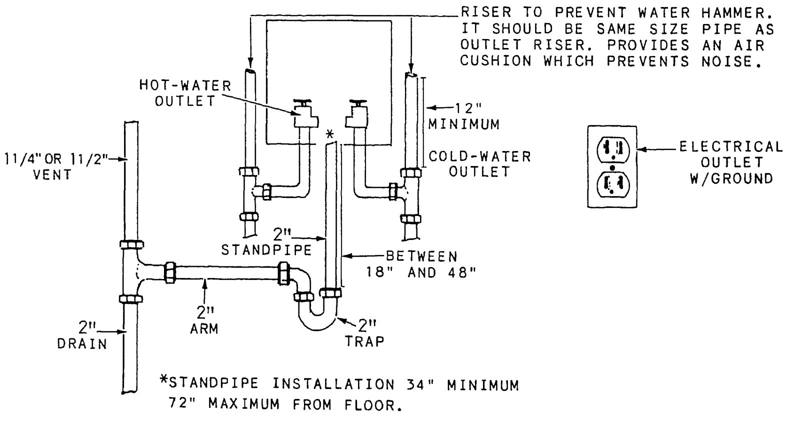


Figure 12-31.—Automatic washer installation.

Table 12-2.—Troubleshooting Chart

PROBLEMS	POSSIBLE CAUSE	CORRECTIVE ACTION
Motor will not run.	No power to machine.	Check outlet.
	Door switch or other safety control in motor circuit.	Check controls for operation and replace if defective.
	Faulty water level control.	Replace control.
	Faulty motor.	Repair or replace motor.
	Faulty timer.	Replace timer.
Machine will not shut off.	Defective timer.	Replace timer.
	Break in wiring.	Repair wiring.
Timer will not advance to next cycle.	Defective timer motor.	Replace timer motor.
	Bound timer shaft or knob.	Clear knob from panel.
	Faulty water level control.	Replace control.
NOTE: Timer does not advance during water fill period until the water level switch has been satisfied.		
Incorrect fill or temperature.	Faulty water level control.	Replace control.
	Faulty thermal element in mixing valve.	Repair or replace.
	Hot-water supply inadequate.	Check temperature setting and capacity.
	Reversed hoses.	Connect hoses correctly.
No water.	Water valves closed.	Turn on valves.
	Hoses kinked.	Unkink hoses.
	Screen in fill hose clogged.	Clean out screen.
	No power to fill solenoid.	Replace solenoid.
	Faulty water level control.	Replace control.
	Machine not turned on.	Check controls and power at outlet.
Water will not shut off.	Defective timer. (Time fill washer)	Replace timer.
	Defective water level control.	Replace control.
	Foreign particles in mix and fill valve.	Clean out valve.
	Defective valve.	Replace valve.

Table 12-2.—Troubleshooting Chart—Continued

PROBLEMS	POSSIBLE CAUSE	CORRECTIVE ACTION
Water will not drain from washer.	Kinked or clogged drain hose.	Clear drain hose.
	Pump does not run.	Readjust and tighten pump.
	Suds lock.	Remove suds, add cold water.
	Faulty transfer valve.	Replace valve.
	Defective timer.	Replace timer.
	Loose belt.	Adjust belt.
No spray rinse.	No water supply.	Same as no water.
	Defective timer.	Replace timer.
Slow spin.	Belt or clutch slips.	Adjust belt.
Excessive vibration.	Washer not level.	Level washer by adjusting leg screws.
	Weak flooring.	Reinforce floor.
	Unbalanced load.	Redistribute load.
	Rubber cups not on feet.	Install cups on feet.
	Damaged snubber or suspension bolts.	Replace snubber.
No agitation.	Motor failure.	Repair or replace.
	Faulty timer contacts.	Replace timer.
	Faulty transmission.	Repair or replace.
	Defective control solenoid.	Replace solenoids.
	Broken linkage.	Repair or replace.
	Faulty water level switch.	Replace switch.
Water leakage.	Inlet hose loosely connected to valve.	Tighten hose connection.
	Drain hoses not tight on pump.	Tighten hose clamps.
	Broken hose.	Repair hose.
	Leaky gasket.	Replace gasket.
	Cracked housing.	Replace parts.

PROBLEMS	POSSIBLE CAUSE	CORRECTIVE ACTION
No recirculation of water during agitation.	Jammed pump.	Clean out pump.
	Defective pump drive.	Replace coupling or tighten.
	Clogged hose.	Clean out hose.
	Defective distribution valve.	Clean out or replace valve or solenoid.
Torn clothing.	Improper bleach usage.	Add bleach to water before loading clothes in tub or dilute bleach well before adding.
	Broken agitator.	Replace agitator.
	Defective basket.	Replace basket.

checklist for some of the common problems, causes, and ways to fix them.

RESIDENTIAL CLOTHES DRYERS

Automatic clothes dryers have two main advantages over the old clothesline process. First, the laundry drying job is much faster with the automatic dryer. The user does not spend as much time setting up the process and the actual drying operation takes less time. The other advantage of an automatic drying scheme is that it can be used at any time of the day, in any season of the year, and under any sort of weather conditions.

Depending on the type of heat energy used, clothes dryers may be divided into two general classes: electric dryers and gas dryers. The source of heat in the electric dryer is obtained electrically by a heating element mounted in the dryer; the heating element is controlled by a centrally located thermostat and timer. In a gas dryer, the source of heat is derived from ignited gas which is obtained by turning on the gas flow; however, a pilot light must first be burning in the combustion chamber. This pilot ignition is automatic; lighting takes place when a spark is created by turning a knob usually on the dryer control panel.

All dryers, irrespective of heating methods used, are equipped with a forced-air blower to draw in fresh air, force it through a heating assembly, and then channel it into the rotating hamper. The warmed air picks up moisture from the laundry as it passes through the hamper; and the blower finally directs the moisture-laden air through a lint filter and out of the dryer.

The lint filter, located near the output end of the airstream, traps most of the dry, lightweight particles of lint and other foreign materials picked up by the moving air.

The heating assembly in an all electric dryer consists of a set of nichrome heating elements situated in the forced-air steam. The heating assembly in a gas dryer performs exactly the same function, but it uses gas flame heat.

The electrical sections of modern clothes dryers can be rather simple compared to some other kinds of modern appliances. The basic electrical units of a dryer include heating controls that maintain a fairly constant drying temperature and a timer mechanism that turns off the dryer at the end of a selected drying interval. The essential differences between the simpler dryer models and the top-of-the-line versions can be found in the number and types of heat and timer controls.

All automatic dryers include a basic cycle that is normally labeled a "Timed Cycle" on the timer control knob. When operation is done in this mode, the dryer tumbles the laundry continually and regulates the level of the forced air throughout the entire drying interval. The tumbling and heating actions both stop at the end of the selected

drying time. You can set the drying interval to any point between zero and about 180 minutes, depending on the amount and wetness of the load.

INSTALLATION

When installing a dryer, either a new one or one that has been repaired, observe all codes and ordinances that apply to the particular dryer. The information below will help you in installing, repairing, and locating a dryer.

- Leave enough space around the dryer for ease of installation, use, and service.
- If the dryer is to be installed in a confined area, such as a closet or bathroom, it must be exhausted to the outside. Furthermore, it must have enough space around it and enough air circulation to operate properly.
- The electric service should conform with the National Electric Code as well as local codes and ordinances.
- When gas is used as the heat source, the installation must conform to the National Fuel Gas Code and local codes and ordinances.
- Never exhaust the dryer into a chimney or any other duct or vent. The dryer must have its own exhaust system.
- Before putting a dryer into use after installing or servicing, replace all access and service panels.
- If still attached, read and follow all caution and direction labels attached to the dryer.
- While servicing, review the wiring diagram that accompanies the dryer. This diagram is usually attached to the access panel.
- The dryer vent should not exceed a maximum length of 4 feet, primarily because the buildup of condensation increases the time required to dry the clothes.

OPERATION

Automatic clothes dryers operate on a simple principle, involving the following essential parts:

- An exhaust fan
- Automatic controls
- A perforated metal drum
- An electric motor to rotate the drum
- A source of heat—either gas or electric

In operation, wet or damp clothes are placed into the drum, and after the door is closed, the thermostatic control is set to the correct heat level; the timer is also set to the desired running time. The best temperature and running time combination depends on the type of clothing, the material of which it is made, the weight of the clothing, and the amount of water it contains. The correct combination for various loads is normally indicated on a chart near the control knobs, or consult the owner's manual.

Once the correct control combination has been set, the drum begins to rotate at about 50 revolutions per minute, and the heat turns on to start the drying function. Air circulation is provided simultaneously by the motor-driven fan, circulating the heated air through the clothing. Baffles on the sides of the drum tend to carry the clothes to the top of the dryer drum, at which time they drop to the bottom. These baffles prevent the clothes from lumping together and provide a tumbling action that speeds up the drying process. The door may be opened at any time during the cycle. When the controls are functioning properly, any opening of the dryer door stops the dryer cycle, turning off the heater and other motors. If more time remains in the cycle, the drying action resumes when the door is closed; in some cases, the start button must be pressed.

Although a motor drive belt may break from time to time or a bearing becomes jammed, most problems involving automatic clothes dryers are in the automatic controls. In most cases, the contacts become worn, wiring becomes short-circuited or open, and so on.

TROUBLESHOOTING

You need to be acquainted with the operation and functioning of both the mechanical and electrical systems. Although the various types of clothes dryers may differ in appearance and location of controls, they all operate on the same principles and are fundamentally similar in servicing. Clothes dryer timers are quite similar to those on automatic washing machines, while thermostats used in automatic dryers are the same type as those used on electric ranges.

Since the only moving parts consist of the motor, drive, drum, and exhaust fan, the clothes dryer, when properly installed, should give years of trouble-free service. When called on, the service personnel should be familiar with the recommendations and specifications of the particular manufacturer's service manual to

replace any worn-out or faulty component correctly. When a dryer does not operate properly, always try the service manual first. However, the following list may be used for further troubleshooting and repair should it become necessary.

A. Problem: The motor does not start.

Probable cause

1. Service cord disconnected.
2. Tripped circuit breaker or blown fuse.
3. Loose or broken electrical wire.
4. Loading door open.
5. Defective door switch.
6. Defective motor.

Remedy

1. Reconnect the service cord.
2. Look for a possible overload or short circuit and then reset the circuit breaker or replace the blown fuse.
3. Use the wiring diagram that accompanies the dryer and check all circuits and connections.
4. Close the loading door and try to start.
5. Repair or replace the door switch.
6. Repair or replace the motor.

B. Problem: The dryer does not shut off.

Probable cause

1. Timer motor jammed.
2. Clock spring broken.
3. Improper positioning of the stop pin.
4. Contact points in the timer are closed.
5. Grounded motor, or motor winding is shorted out.

Remedy

1. Pull the dial slightly away from the front panel; it may be binding.
2. Replace the clock.
3. Remove the dial; trim the edge of the fin behind the word *off*. Trim the edge until the dial can advance enough to break the contact points turning the shaft over in the dial.
4. Pull the timer dial away from the front panel and turn it to the OFF position. Replace the timer assembly.
5. Replace the motor.

C. Problem: Drying is slow.

Probable cause

1. Clothes are too wet when transferred to the dryer.
2. Lint cloggage in the lint box.
3. Thermostat set too low.
4. Low voltage.
5. Dryer overloaded; too many clothes.

Remedy

1. Check the spin cycle.
2. Clean the lint box.
3. Reset the thermostat.
4. Check the power supply.
5. Do not overload.

D. Problem: The dryer is noisy.

Probable cause

1. Incorrect alignment of the suction fan.
2. Loose fan or motor pulley; loose or dry belt.
3. Loose items between the drum and the cylinder housing.

Remedy

1. Align the pulleys; replace defective belts.
2. Apply a thin coating of surface belt dressing on the pulleys.
3. Check between the drum and the cylinder. Tighten all screws.

REFERENCES

Open End Washer MT360EW1DE Technical Manual, Pellerin Milnor Corp., Kenner, La., 1987.

Extractor M30EXTR1AE User Manual, Pellerin Milnor Corp., Kenner, La., 1987.

CHAPTER 13

REFRIGERATION

Learning Objective: Recognize the characteristics and procedures required to service and troubleshoot refrigeration systems.

Modern refrigeration has many applications. The first, and probably most important, is the preservation of food. Most foods kept at room temperature spoil rapidly. This is due to the rapid growth of bacteria. At usual refrigeration temperatures of about 40°F, bacteria grow quite slowly. Food at this temperature keeps much longer. Refrigeration preserves food by keeping it cold.

As you know, the science of refrigeration is based upon the fact that a liquid can be vaporized at any desired temperature by changing the pressure above it. Water, under the ordinary atmospheric pressure of 14.7 psia, boils when its temperature has been raised to 212°F. The same water in a closed tank under a pressure of 67.013 psia will not boil until its temperature has reached 300°F.

This chapter contains information pertaining to refrigerants, their effect, superheated vapor, and subcooling. Also discussed are methods of installing refrigeration equipment and maintaining, servicing, and repairing domestic refrigerators and freezers. Always follow the manufacturer's instruction manual for the equipment you are installing or repairing. Where specific directions or requirements are furnished, follow them.

REFRIGERANTS

Many substances have been used as refrigerants. In past years, the most common has been air, ammonia, sulphur dioxide, carbon dioxide, and methylchloride. Today, fluorinated hydrocarbon refrigerants are being used almost exclusively in air-conditioning systems. New refrigerants are in the process of development at the present time.

The primary requisite for a refrigerant is it should be neither poisonous nor inflammable. There is always the possibility that a leak may develop in the evaporator or cooling coil; the air flowing through the coil then carries the refrigerant into the conditioned spaces. It is therefore essential that refrigerants should be nontoxic and nonflammable.

Fluorinated hydrocarbons are refrigerants derived from hydrocarbons and contain chlorine and fluorine. They are noncorrosive, nonflammable, nontoxic, nonexplosive, clear water-white and have a slightly sweet odor. By building up a molecular structure of hydrocarbons to yield the proper molecular weight and physical properties, chemists can manufacture new refrigerants with boiling temperatures that occur at any design pressure. This has permitted the engineer to improve the design of basic components in the refrigeration cycle by developing more compact equipment at reduced costs.

Different refrigerants can be used to vary the capacity of a compressor. For example, a line of reciprocating compressors may have capacity ratings of 5, 10, 15, and 20 tons with Refrigerant-12 (R-12). When Refrigerant-22 (R-22) is used, the capacity of the same compressors are 8, 15, 23, and 30 tons. You should not change the type of refrigerant used in a system without the approval of the compressor manufacturer.

REFRIGERATING EFFECT

The quantity of heat each pound of refrigerant absorbs while flowing through the evaporator is known as the refrigerating effect. Each pound flowing through the evaporator is able to absorb only the heat required to vaporize it if no superheating takes place. If the liquid approaching the expansion valve were at exactly

the temperature at which it was vaporizing in the coil, the heat the refrigerant could absorb would be equal to its heat of vaporization. In other words, the refrigerating effect is the same as the heat of vaporization. However, the temperature of the liquid approaching the expansion valve is nearly always higher than the temperature of the vaporizing refrigerant in the evaporator. Therefore, the refrigerating effect is always less than the heat of vaporization.

In the theoretical refrigerating cycle, heat is added to the refrigerant liquid only as it flows through the evaporator. Actually, as the liquid flows through the pipeline on its way to the expansion valve and the evaporator, it may either lose or gain heat, depending on whether the temperature of the air surrounding the pipe is higher or lower than the temperature of the liquid. The liquid flowing through the expansion valve can neither gain nor lose heat and, as mentioned previously, the throttling process does not change the enthalpy (heat content) of the refrigerant.

The heat added to each pound of refrigerant in the evaporator is the difference between the enthalpy of the vapor leaving the evaporator and the enthalpy of the liquid-vapor mixture entering the evaporator. As no heat is added to the refrigerant during the throttling process, the heat added in the evaporator must be the difference between the enthalpy of the vapor leaving the evaporator and the enthalpy of the liquid approaching the expansion valve.

SUPERHEATED REFRIGERANT VAPOR

When liquid refrigerant is admitted to a cooling coil, it usually is completely vaporized before it reaches the outlet connection. In as much as the liquid is vaporized at low temperature, the vapor is still cold after the liquid has completely evaporated. As the cold vapor flows through the balance of the coil, it continues to absorb heat and become superheated.

The vapor absorbs sensible heat in the evaporator as it becomes superheated. Therefore, the refrigerating effect of each pound of refrigerant is increased. In other words, each pound of refrigerant absorbs not only the heat required to vaporize it but also an additional amount of sensible heat which superheats it. Although the refrigerating effect of each pound is increased as a result of the superheating, the density is decreased. Superheating of any vapor always decreases its density. Thus, one cubic foot of saturated R-12 vapor at 40°F weighs 1.2927 pounds. If this same cubic foot is superheated 30 degrees (to 70°F), its density decreases to 1.192 pounds per cubic foot—a decrease of approximately 7 1/2 percent. Interpreted practically, this means that the weight of vapor filling the cylinders of a given compressor is decreased by superheating.

On one hand, the capacity of a refrigeration system is increased when superheating of the vapor takes place because the refrigerating effect of each pound of vapor removed has been increased by the sensible heat added during superheating. On the other hand, the refrigerating capacity of a system is decreased because of the decrease in density during superheating. The effect of these two opposing tendencies must be computed to determine whether or not the refrigerating capacity of a system is increased by superheating the vapor in the cooling coils. The various refrigerants are not alike in this respect—each one must be checked individually. For superheat amounting to as much as 40 degrees, R-12 shows a negligibly small change in refrigerating capacity when this superheating takes place inside the cooling coil. The gain due to the additional sensible heat absorbed by the vapor is almost exactly equal to the loss due to its decreased density.

However, superheating of the vapor often takes place after it leaves the evaporator. The vapor absorbs sensible heat while it is flowing through the suction line that connects the evaporator to the compressor. When superheating of the vapor takes place in the suction line, there is no increase in refrigerating capacity to offset the loss due to the increase in volume of the vapor. As a result, superheating of any refrigerant in the suction line decreases the capacity of the compressor in pounds pumped. For fluorinated hydrocarbons, there is a theoretical loss in refrigerating capacity of 1 percent for each 4.3 degrees (approximately) of superheat. Thus, if the vapor entering a compressor has been superheated 21 degrees in the suction line, the refrigerating capacity of the system is decreased by almost 5 percent. For this reason, superheating of the vapor in the suction line of the system should

be prevented. The suction line between the evaporating coil and the compressor is frequently insulated.

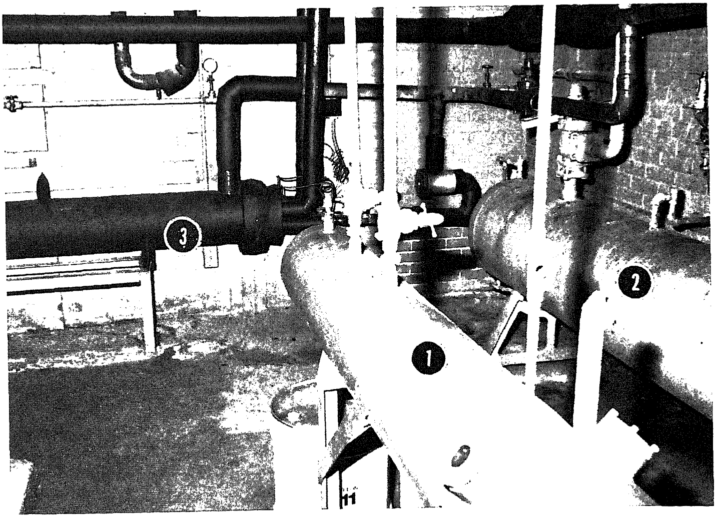
SUBCOOLING

Subcooling is a term used to describe the cooling of a liquid refrigerant, at constant pressure, to a point below the temperature at which it was condensed. Thus, at 117.16 psig, R-12 vapor condenses at a temperature of 100 °F. If, after the vapor has been completely condensed, the liquid is cooled still further to a temperature of 76 °F, it has been subcooled 24 degrees. When a liquid refrigerant can be subcooled either by cold water or by some other means, external to the refrigeration cycle, the refrigerating effect of the system will be increased. (See fig. 13-1.) This is because the enthalpy (heat content) of subcooled liquid is less than the enthalpy of saturated liquid.

INSTALLATION OF REFRIGERATION EQUIPMENT AND UNITS

As a Utilitiesman 2, you will be involved in the installation of refrigeration systems. Even though you usually follow plans and work under supervision, you may be a crew leader. It is important for you to understand the basic requirements applicable to various types of installations.

When in installing a refrigeration or air-conditioning plant, make sure you do not allow dirt, scale, sand, or moisture to enter any part of the refrigerant system. Since air contains moisture, its entrance into the circuit should be controlled as much as possible during installation. Most maintenance problems come from careless erection and installation. All openings to the refrigerant circuit, piping, controls, compressor, condensers, and so on, must be adequately sealed



1. Oil Receiver. 2. Refrigerant Receiver. 3. Liquid Refrigerant Subcooler.

54.606

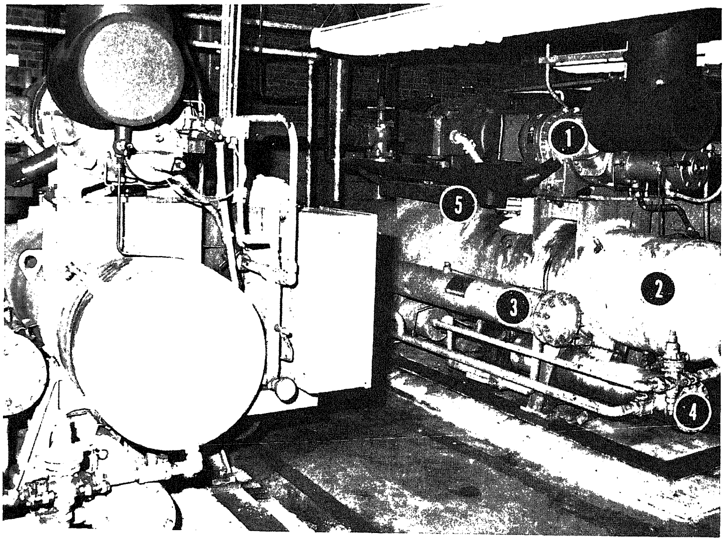
Figure 13-1.—Components of a low-temperature plant.

when work on them is not in progress. The R-12 refrigerant is a powerful solvent that readily dissolves foreign matter and moisture which may have entered the system during installation. This material is soon carried to the operating valves and the compressor. It becomes a distinct menace to bearings, pistons, cylinder walls, valves, and the lubricating oil. Scoring of moving parts frequently occurs when the equipment is first operated, starting with minor scratches that increase until the operation of the compressor is seriously affected.

Under existing specifications, copper tubing and copper piping needed for installation should be cleaned, deoxidized, and sealed. When there is a question about cleanliness of tubing or piping to be used, each length of pipe should be thoroughly blown out with a strong blast of dry air and cleaned with a cloth swab attached to copper wire pulled back and forth in the tube until it is clean and shiny. Then, the ends of the tubes should be sealed until connected to the rest of the system.

EFFECTS OF MOISTURE

As little as 15 to 20 parts of moisture per million parts of R-12 can cause severe corrosion in a system. The corrosion results from hydrochloric acid formed by R-12 in contact with water. A chemical reaction takes place between the acid and the iron and copper in the system to form corrosion products. A strong acid combined with high discharge and compressor temperature can cause decomposition of lubricating oil and produce a sludge of breakdown products. Either the corrosion or the oil breakdown products can plug valves, strainers, and driers and cause a serious casualty.



1. Compressor.
2. Oil Separator and Reservoir.
3. Oil Cooler.
4. Oil Filters.

54.607

Figure 13-2.—Low-temperature screw or helix compressor system.

The formation of ice in expansion valves and capillary tubes can occur when operating below 32 °F with a minute quantity of moisture.

LOCATION OF EQUIPMENT

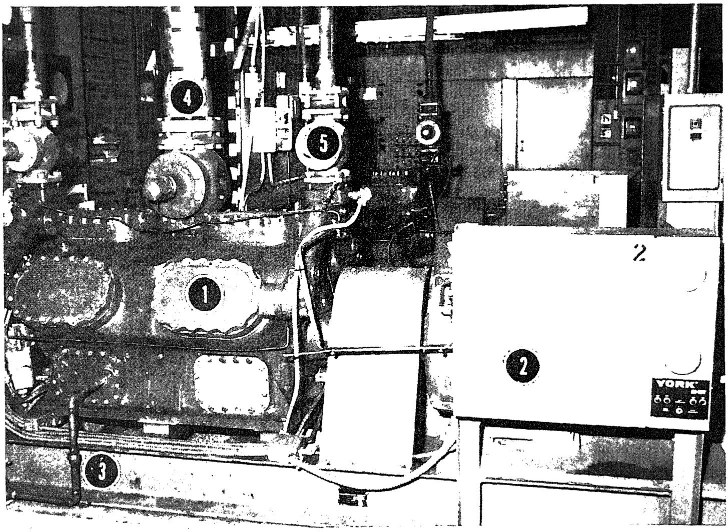
Adequate space should always be left around major portions of equipment for servicing purposes; otherwise, the equipment must be moved after installation so serviceable parts are accessible. (See figs. 13-2 and 13-3.) Compressors require overhead clearance for removal of the head, discharge valve plate, and pistons with side clearance to permit removal of the flywheel and crankshaft where necessary. Water-cooled condensers require a free area equal to the length of the condenser at one end to provide room for cleaning tubes, installing new tubes, or removing of the condenser tube assembly. Space is needed for servicing valves and accessory equipment. Service openings and inspection panels on unitary equipment require generally at least 18 inches of clearance for removal of the panel. Air-cooled condensing units should be placed in a location that permits unrestricted flow of air for condensing, whether the condenser is in a unitary piece of equipment or separate.

VENTILATION

Adequate ventilation should be supplied to all air-cooled condensing units; otherwise, overloading of the motor and loss of capacity results.

REFRIGERANT PIPING—GENERAL PRECAUTIONS

Certain general precautions for the installation of refrigerant lines should be followed. When the receiver is above the cooling coil, the liquid line



1. Compressor.
2. Control Panel.
3. Oil Return from Reservoir.
4. Suction Line.
5. Hot Gas Discharge Line.

54.608

Figure 13-3.—Twelve cylinders semi-hermetic reciprocating direct drive compressor.

should be turned up before going down to the evaporator. This inverted loop prevents siphoning of the liquid from the receiver over into the cooling coil through an open or leaking expansion valve during compressor shutdown periods. If siphoning starts, the liquid refrigerant flashes into a gas at the top of the loop, breaking the continuity of the liquid volume and stopping the siphoning action. Where the cooling coils and compressors are on the same level, both the suction and liquid lines should be run to the overhead and then down to the condensing unit, pitching the suction line toward the compressor to ease oil return. On close-coupled installations, running both lines up to the overhead helps to eliminate vibration strains as well as provide the necessary trap at the cooling coil.

INSTALLATION OF REFRIGERANT PIPING

Prepare pipe and fittings with care, particularly in cutting copper tubing or pipe to prevent filings or cuttings from entering the pipe. The small particles of copper should be completely removed since the finely divided copper may pass through the suction strainer. The tube should be cut square and all burrs and dents should be removed to prevent internal restrictions and to permit proper fit with the companion fittings. If a hacksaw is used to cut, a fine-toothed blade should be used, preferably 32 teeth per inch. The use of a hacksaw should be avoided whenever possible.

When making silver-solder joints, brighten up the ends of the tubing or pipe with a wire brush or crocus cloth to make a good bond. Do not use sandpaper, emery cloth, or steel wool for this cleansing, as this material may enter the system and cause trouble.

Acid should never be used for soldering, nor should flux be used if its residue forms an acid. Use flux sparingly so no residue will enter inside the system and eventually be washed back to the compressor crankcase. If tubing and fittings are improperly fitted because of distortion, too much flux, solder, and brazing material may enter the system.

The temperature required to solder or braze joints causes oxidation within the tubing. The oxidation eventually will be removed by the R-12 flow after the system is in operation. The oxide breaks up into a fine powder to contaminate the lubricant in the compressor and to plug strainers and driers. To eliminate this possibility, provide a neutral atmosphere within the tube being soldered or brazed. Use gas-bled nitrogen through the tubing during soldering or brazing and for a sufficient time after the bond is made until the heat of the copper has been reduced below the temperature of oxidation. Never allow liquid to touch your skin. Contact causes freezing of the skin. This method works for repair of a leak after the system has been charged with R-12 to blow out any traces of the refrigerant vapor and oil to prevent the breakdown of any refrigerant which may create harmful acid or permit contamination of the system. Carbon dioxide may be substituted when nitrogen is not available.

All joints should be silver soldered and kept to a minimum to reduce leaks. Special copper tube fittings designed for refrigeration service should be used since these are manufactured with close tolerances to assure tight capillary joints in the brazing process.

SAE flare joints are generally not desired, but when necessary, care should be taken in making the joint. The flare must be of uniform thickness and should present a smooth, accurate surface free from tool marks, splits, or scratches. The tubing must be cut square, provided with a full flare, and any burrs and saw filings removed. The flare seat of the fitting connector must be free from dents or scratches. The flare can best be made with a special swivel head flaring tool, available as a general stores item, which remains stationary and does not tear or scar the face of the flare in the tubing. Oil should not be used on the face of the flare, either in making up the flare or in securing it to the fitting, since the oil will eventually be dissolved by the refrigerant in the system and cause a leak through the displacement of the oil. The flare joint should always be tightened with two wrenches—one to turn the nut and the other to hold the connecting piece to avoid strain on the connection and cause a leak.

Where pipe or tubing has to be bent, bends should be made with special tools designed for this type of work. Do not use rosin, sand, or any other filler inside the tubing to make a bend. Threaded joints should be coated with a special refrigerant pipe dope. In an emergency, use a thread compound for making up a joint; remember R-12 is a hydrocarbon that dissolves any compound containing oil. A compound containing an acid or one whose residual substance forms an acid should not be used. The use of a thick paste made of fresh litharge and glycerine makes a satisfactory joint compound; however, the joint should be thoroughly cleaned with a solvent to eliminate oil or grease. Thread

compounds should be applied to the male part of the thread after it has entered the female coupling one and one-half to two threads to prevent any excess compound from entering the system.

When securing, anchoring, or hanging the suction and liquid lines, be sure and allow enough flexibility between the compressor and the first set of hangers or points where the lines are secured to permit some degree of freedom. This relieves strain in the joints of these lines at the compressor due to compressor vibration.

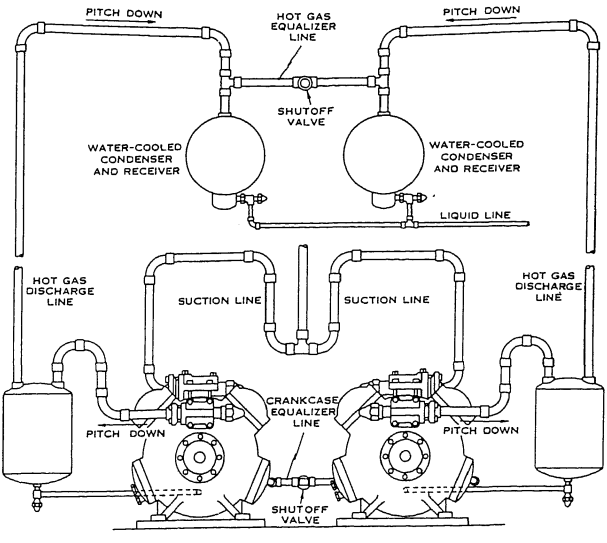
MULTIPLE COMPRESSOR INSTALLATIONS

Parallel operation of two or more reciprocating compressors should be avoided unless there are strong and valid reasons for not using a single compressor. In a situation where two compressors must be used, extreme care in sizing and arranging the piping system is essential.

An acceptable arrangement of two compressors and two condensers is shown in figure 13-4. An equalizer line connects the crankcase at the oil level of each machine. Therefore, the oil in both machines will be at a common level. If machines of different sizes are used, the height of the bases beneath the machines must be adjusted so the normal oil level of both machines is at the same elevation; otherwise, the oil accumulates in the lower machine.

This arrangement is called a single-pipe crankcase equalizer. It can be used only on those machines with a single equalizer tapping entering the crankcase in such a position that the bottom of the tapping just touches the normal oil level.

Another method of piping to maintain proper oil level in two or more compressors uses two equalizer lines between the crankcase: one above the normal oil level and one below. The double equalizer system must be used on compressors having two equalizer tappings. A single equalizer line on machines having two equalizer tappings should never be used.



Reprinted by permission of the Trane Company.

54.609X

Figure 13-4.—Parallel compressors with separate condensers.

The lower oil equalizer line must not rise above the oil level in the crankcase and should be as level as possible. This is important since the oil builds up in one crankcase if the line rises. The upper equalizer line is a gas line intended to prevent any difference in crankcase pressure which would influence the gravity flow of oil in the lower equalizer line or the level of oil in the crankcase. This upper line must not dip and care should be taken to eliminate pockets in which oil could accumulate to block the flow of gas. Valves in the crankcase equalizer lines are installed with the stems horizontal, so no false oil levels are created by oil rising over the valve seat, and to minimize flow resistance.

It is poor practice to skimp on piping when making up these equalizer lines. Oversize piping is preferred to undersize piping. General practice indicates the use of oil equalizer lines equal to the full size of the tapping in the compressor.

The discharge lines from the compressors are also equalized before they enter the condensers. This, in effect, causes the individual condensers to function as a single unit. This is the most critical point in the piping system. It is here that pressure drop is extremely important—a pressure drop of 0.5 psi being equal to a 1.0 foot head of liquid. Excessive pressure drop in the equalizer line may rob one condenser of all liquid by forcing it into the other condenser. One of the results may be the pumping of large quantities of hot refrigerant vapor into the liquid lines from the condenser of the operating compressor. This could reduce the capacity of the system materially.

For that reason, the equalizer line should be just as short and level as possible. A long equalizer line introduces an unequal pressure in condensers if one of the compressors is not operating. The refrigerant then accumulates in the condenser of the nonoperating compressor. The equalizer line should also be generously sized and should be equal to or larger than the discharge line of the largest compressor being used.

If the condensers are more than 10 feet above the compressor, U-traps or oil separators should be installed in the horizontal discharge line where it comes from each compressor. The traps or separators prevent the oil from draining back to the compressor head on shutdown.

Should a single compressor or multiple compressors with capacity modulation be used in an instance of this kind, another solution may be dictated. When a compressor unloads, less refrigerant gas is pumped through the system. The velocity of flow in the refrigerant lines drops off as the flow decreases. It is necessary to maintain gas velocities above some minimum value to keep the entrained oil moving with the refrigerant. The problem becomes particularly acute in refrigerant gas lines when the flow is upward. It does not matter whether the line is on the suction or discharge side of the compressor; the velocity must not be allowed to drop too low under low refrigerant flow conditions.

Knowing the minimum velocity, 1,000 feet per minute (fpm), for oil entrainment up a vertical riser and the minimum compressor capacity, the designer of the piping can overcome this problem using a double riser.

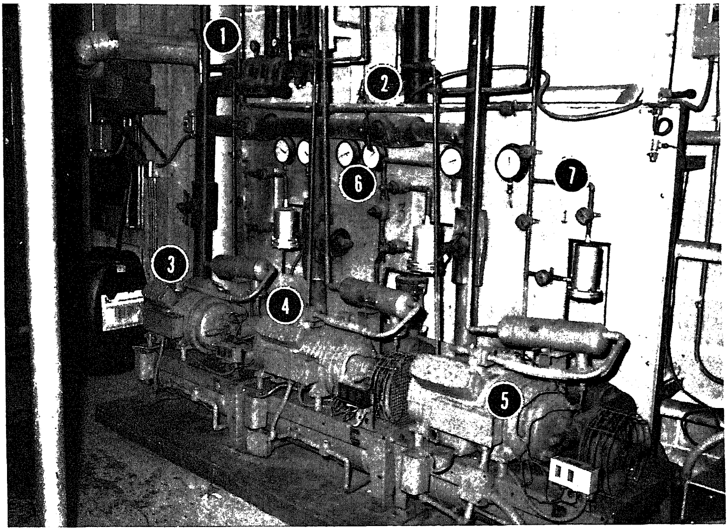
The smaller line in the double riser is designed for minimum velocity, at the minimum step, of compressor capacity. The larger line is sized to assure that the velocity in the two lines at full load is approximately the same as in the horizontal flow lines. A trap of minimum dimensions is formed at the bottom of the double-riser assembly which collects oil at minimum load. Trapped oil then seals off the larger line so the entire flow is through the smaller line.

If an oil separator is used at the bottom of a discharge gas riser, the need for a double riser is eliminated. The oil separator will do as its name implies—separate the major part of the oil from the gas flowing to it and return the oil to the compressor crankcase. Since no oil separator is 100-percent effective, the use of an oil separator in the discharge line does not eliminate the need for double risers in the suction lines of the same system if there are vertical risers in the suction lines.

When multiple compressors with individual condensers are used, the liquid lines from the condenser should join the common liquid line at a level well below the bottoms of the condensers. The low liquid line prevents gas from an "empty" condenser from entering the line because of the seal formed by the liquid from other condensers.

The condenser water supply for a multiple system using individual condensers should be controlled by a common water regulating valve, so each condenser receives a proportional amount of the condenser water.

Frequently, when multiple compressors are installed, only one condenser is provided. Such installations are satisfactory only as long as all of the compressors are operating at the same suction pressure. However, several compressors may occasionally be installed which operate at different suction pressures—the pressures



1. **Suction Pressure Regulates for Five Different Boxes to Control Temperatures, Ranging from 50 to 35 Degrees.**
2. **Head Pressure Control to Hold Head Pressure at Given Pressure by Using Hot Gas Bypass Method.**
3. **Medium-Temperature Compressor.**
4. **Medium- or Low-Temperature Compressor. (Standby Compressor)**
5. **Low-Temperature Compressor.**
6. **High-Low Pressure Gauges.**
7. **Liquid Line Dryer Assembly.**

NOTE: Two Receivers Under Each Compressor.

54.610

Figure 13-5.—Compressor plant servicing walk-in boxes of different temperature ranges.

corresponding, of course, to the various temperatures needed for the different cooling loads. (See fig. 13-5.) When this is the case, a separate condenser must be installed for each compressor or group of compressors operating at the same suction pressure. Each compressor, or group of compressors, operating at one suction pressure must have a complete piping system with an evaporator and condenser, separate from the remaining compressors operating at other suction pressures. Separate systems are required because the crankcase of compressors operating at different suction pressures cannot be interconnected. There is no way of equalizing the oil return to such compressors.

The suction connection to a multiple compressor system should be made through a suction manifold, as shown in figure 13-4. The suction manifold should be as short as possible and should be taken off in such a manner that any oil accumulating in the header returns equally to each machine.

Evaporative condensers can be constructed with two or more condensers built into one spray housing. This is accomplished quite simply by providing a separate condensing coil for each compressor, or a group of compressors, operating

at the same suction pressure. All of the condensing coils are built into one spray housing; this provides two or more separate condensers in one condenser housing.

OTHER REFRIGERATING EQUIPMENT

Other types of refrigerating equipment you may find at your activity—other than the refrigerators discussed above—include ice-making machines (either flake ice or ice cubes), ice cream plants and dispensing cabinets, beverage coolers, and water coolers.

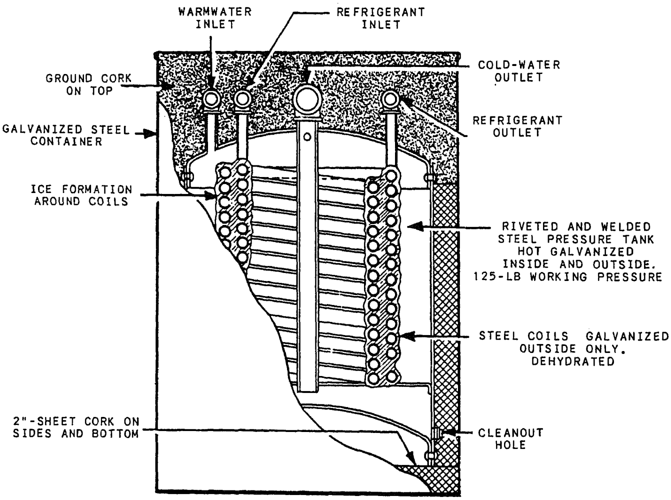
The ice-making machines are self-contained, automatic machines which continuously produce ice until the built-in storage bin is full. The primary difference in the design of these machines and the refrigerators lies in the evaporator. In some ice machines, water is sprayed onto the evaporator where it freezes and is scraped off to form flake ice. In other ice machines, molds (similar to ice cube trays) are used in the evaporator to freeze water into cubes. At the end of the freezing cycle, the molds are heated and the cubes drop into the storage bin.

A desirable piece of equipment at any Seabee activity is the ice cream plant. Two sizes are currently available. One has a 6-quart freezing unit with a hardening and dispensing capacity of 20 gallons. The other has a 20-quart freezing plant with a hardening and dispensing capacity of 80 gallons. Both are self-contained skid-mounted units that are electrically powered.

Ice cream dispensing cabinets are also available. The cabinets are equipped with steel cans to store 30, 35, or 40 gallons of ice cream. They are electrically operated and have corrosion-resistant tops, lids, and hardware.

Bottled and canned beverage coolers used in the Navy are similar to the type commonly found in grocery stores and other commercial establishments. According to size, these coolers hold approximately 528 to 768 12-ounce bottles. The coolers have corrosion-resistant hardware, removable wire compartment dividers, covers, and an apron.

A common device in many areas is the water cooler. It is designed to provide water for drinking at a temperature under 50 °F. Most water coolers are self-contained with the condensing unit



54.340

Figure 13-6.—Storage type of water cooler.

in the lowest part of the cabinet. Two types of water coolers are as follows: instantaneous and storage. The instantaneous type only cools water when it is being drawn; the storage type maintains a reservoir of cooled water. The principles of operation are the same as for refrigerators—only the design of the evaporator varies. One instantaneous method used is to place coils in a flooded evaporator through which the water flows. A second instantaneous method is to use double coils with water flowing through the inner coil refrigerant flowing in the space between the inner coil and the outer coil. A third method is to coil the tubing in a water storage tank. This allows refrigerant to flow through it. (See fig. 13-6.)

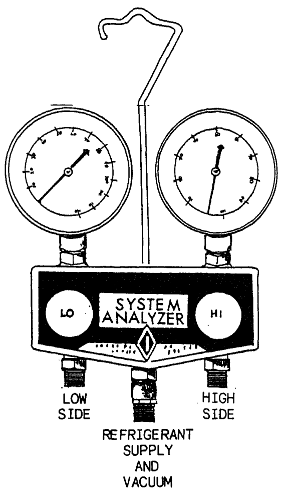
Other common types of refrigerating equipment include domestic refrigerators and home freezers, discussed later in this chapter.

MAINTAINING, SERVICING, AND REPAIRING OF REFRIGERATION EQUIPMENT

As a Utilitiesman, you must be able to perform various duties in maintaining, servicing, and repairing refrigeration equipment. This phase of our discussion provides information on different jobs that you may be called upon to handle. When information here varies from that in the latest federal or military specifications, the specifications apply. You will find the "Troubleshooting Checklist," presented in this chapter, helpful in locating and correcting troubles. It is not intended to be all encompassing. Manufacturers also provide instruction manuals to aid you in maintaining and servicing their equipment.

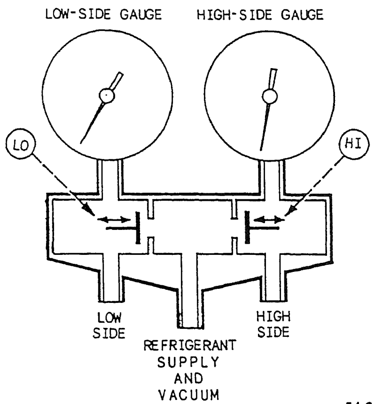
TYPICAL REFRIGERATION SERVICING EQUIPMENT

Repair and service work on a refrigeration system consists mainly of containing refrigerant and measuring pressures accurately. One piece of equipment is the refrigerant manifold test set (fig. 13-7). It consists of a 0-500 psig gauge for measuring pressure at the compressor high side, a compound gauge (0-250 psig and 0 to −30 inches of mercury) to measure the low or suction side, valves to control admission of the refrigerant to the refrigeration system, and the connections and lines required to connect the test set to the system. Depending on test and service requirements, the test set can be connected to the low side, the high side, a source of vacuum, or a refrigerant cylinder. A swiveling hanger allows the test set to be hung easily, and the three additional blank connections allow for securing the open ends of the three lines when the test set is not in use. There is always a path from the low-side and high-side input to the low-side and high-side gauge (fig. 13-8).



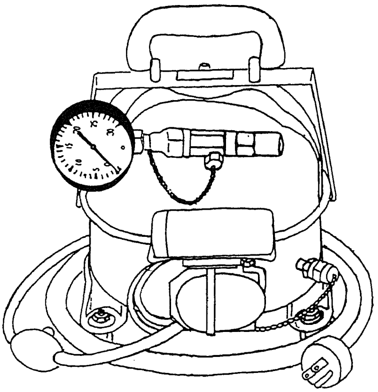
54.341

Figure 13-7.—Refrigerant manifold test set.



54.342

Figure 13-8.—Internal view of refrigerant manifold test set.



54.343

Figure 13-9.—Portable vacuum pump.

Another important piece of equipment is the portable vacuum pump. The type listed in the Seabee Table of Allowance is a sealed unit consisting of a single-piston vacuum pump driven by an electric motor. A vacuum pump is the same as a compressor, except the valves are arranged so the suction valve is opened only when the suction developed by the downward stroke of the piston is greater than the vacuum already in the line. This vacuum pump can develop a vacuum close to − 30 inches of mercury, which can be read on the gauge mounted on the unit (fig. 13-9). The pump is used to reduce the pressure in a refrigeration system below atmospheric pressure.

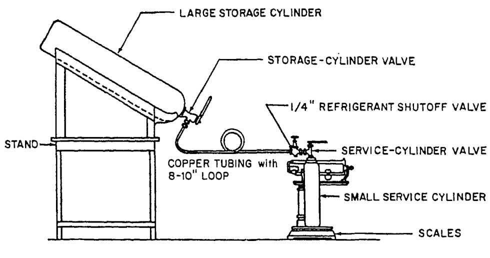
Hermetic refrigeration systems used by the Navy are manufactured by various manufacturers and, because of this, the connectors and size of tubing vary. The Table of Allowance provides for a refrigeration service kit that contains several adapters, wrenches, and other materials to help connect different makes of systems to the refrigerant manifold test set and the vacuum pump lines. A table affixed to the lid of the storage container identifies the adapter you should use for a particular refrigeration unit.

TRANSFERRING REFRIGERANTS

Refrigerants are shipped in compressed gas cylinders as a liquid under pressure. Liquids are usually removed from the shipping containers and transferred to a service cylinder.

Before attempting transfer of refrigerants from a container to a cylinder, precool the receiving cylinder until its pressure is lower than that of the storage container or cylinder. Precool by placing the cylinder in ice water or a refrigerated tank. You must also weigh the service cylinder, including cap, and compare it with the tare weight stamped or tagged on the cylinder. The amount of refrigerant that may be placed in a cylinder is 85 percent of the tare weight (the weight of a full cylinder and its cap minus the weight of the empty cylinder and its cap). The tare capacity of standard Navy R-12 cylinders may be ascertained from the following:

Capacity of cylinder	Diameter (inches)	Length of cylinder body (inches)
50 pounds	8 1/4	26 3/4
10 pounds	4 3/16	25 1/4



54.167

Figure 13-10.—Method of transferring refrigerants to service cylinders.

Connect a flexible charging line on a 1/4-inch copper tube several feet long with a circular loop about 8 to 10 inches in diameter. Be sure to install a 1/4-inch refrigerant shutoff valve (fig. 13-10) in the charging line to the service cylinder. This valve should be inserted so no more than 3 inches of tubing is between the last fitting and the valve itself. This arrangement prevents the loss of refrigerant when the service drum is finally disconnected. The entire line must be cleared of air by leaving the flare nut on the service cylinder loose and cracking the storage cylinder valve. This allows refrigerant to flow through the tubing, clearing it. After clearing, tighten the flare nut and then open the valve on the service cylinder, the valve on the storage cylinder, and then the 1/4-inch valve in the refrigerant line. When the weight of the service cylinder shows a sufficient amount of refrigerant is in the serviced cylinder, close all valves tightly, and disconnect the charging line at the service cylinder.

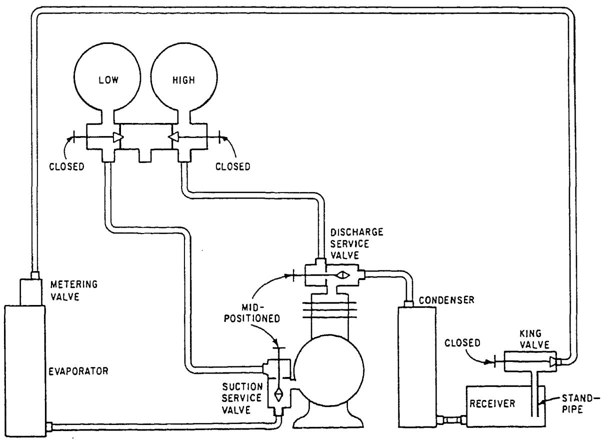
To warm refrigerant containers or cylinders for more rapid discharge, use care to prevent a temperature above 120 °F, as the fusible plugs in the cylinder and valve have a melting point of about 157 °F.

PUMPING DOWN

Quality refrigeration repair includes preventing loss of refrigerant in the system. Whenever a component is removed from the system, the normally closed system is opened and, unless precautions are taken, refrigerant is lost to the atmosphere. The best way to contain the refrigerant (gas and liquid) is to trap it in the condenser and receiver by pumping down the system.

To pump down the system, secure electric power to the unit, connect the refrigerant manifold test set, as shown in figure 13-11, close the receiver stop (king) valve (by turning the valve stem inwards as far as it will go), and close the LO and HI valves.

Tighten the gland nut if it appears loose. Start the compressor with the compressor discharge and suction service valves in midposition. Operate the compressor until the pressure in the low side of the system shows 0-1 psig on the compound gauge. Stop the compressor unit. If the pressure rebuilds appreciably, operate the unit again until pressure registers between 0-1 psig. Repeat this step until the pressure no longer rebuilds appreciably. If suction pressure remains at about 1 pound as read on the compound gauge, then



54.568

Figure 13-11.—Connections for pumping down the system.

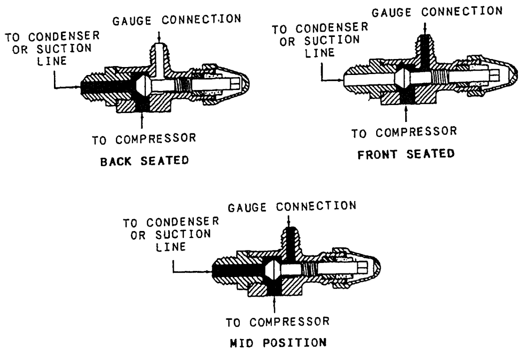


Figure 13-12.—Three-way service valve positions.

front seat the suction and discharge service valves. (See fig. 13-12.) This procedure traps practically all of the refrigerant in the condenser and receiver.

REMOVING REFRIGERANT FROM THE SYSTEM

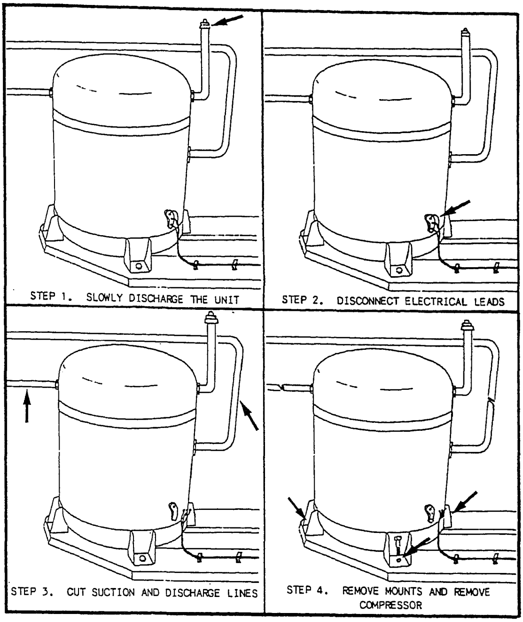
The refrigerant is withdrawn from the condensing unit through the liquid valve at the receiver. Disconnect the liquid line from the liquid valve after pumping the evaporator down according to the manufacturer's instructions. It is not necessary to disconnect the liquid line in units that have a two-way liquid valve at the receiver. Provide a connection of 3 to 4 feet of soft copper tubing between the receiver valve and a clean, empty, precooled service cylinder. Weigh the cylinder frequently to avoid overfilling. Never fill a cylinder beyond 85 percent of its rated capacity because it may rupture from hydraulic pressure with a rise in temperature. Leave the flare nut loose at the refrigerant cylinder valve and crack the liquid valve on the receiver to clear air from the tubing. After clearing, tighten all connections. Open the cylinder and liquid valves. If refrigerant flow to the cylinder is stopped, it may be necessary to lower the cylinder pressure by cooling the cylinder with cold water or ice. When the receiver pressure has been lowered to the pressure equivalent to the service cylinder temperature, all of the refrigerant has been removed. Close the cylinder and receiver valves. An overcharge of refrigerant is removed in the same way, except the connection from the system is made at the compressor discharge service valve on the compressor head.

REMOVING AND REPLACING COMPONENTS

The first step in removing components in a refrigeration system for repair and/or replacement is to pump down the system. As you have learned, this procedure traps practically all of the refrigerant in the condenser and receiver. By proper positioning of the valves, you can remove the evaporator, expansion valves, and compressor (with connecting lines) with a minimum loss of refrigerant.

REMOVING EXPANSION OR FLOAT VALVES

To help ensure good results in removing expansion or float valves, pump the system down to a suction pressure of just over zero; do this at least three times and then remove the expansion valve. Plug the opened end of the liquid line and evaporator coil to prevent air from entering the system. Repair or replace the expansion valve and connect it to the liquid valve. Crack the receiver service valve to clear air from the liquid line and the expansion valve. Connect the expansion valve to the evaporator coil inlet and tighten the connection. Pump a vacuum into the low side of the system to remove any air.



54.294

Figure 13-13.—Removing defective hermetic compressor.

REPLACING THE EVAPORATOR

To replace an evaporator, pump down the system and disconnect the liquid and suction lines. Then, remove the expansion valve and the evaporator. Make the necessary repairs or install a new evaporator as required. Replace the expansion valve and connect the liquid and suction lines. Remove moisture and air by pumping a vacuum on the system. When the evaporator is back in place, pump a deep vacuum as in starting a new installation for the first time. Check for leaks and correct them if they occur. If leaks do occur, be certain to repair them; then, pump the system into a deep vacuum. Repeat the process until no more leaks are found.

REMOVING THE COMPRESSOR

By pumping down the system, most of the refrigerant is trapped in the condenser and the receiver. To remove the compressor from service, isolate the compressor by closing the suction and discharge service valves and then equalizing the pressure within the compressor. Both suction pressure in the crankcase and head pressure can be equalized to atmospheric pressure by either positioning the service valves to the vent position or cracking the connections to the compressor. When the lines to the compressor are disconnected, be certain to cover or block them to prevent dirt and moisture from entering them until another compressor can be installed or the original repaired and replaced. When a compressor has been installed, the air must be evacuated by drawing a vacuum on the system and then the system must be recharged.

REMOVING THE HERMETIC UNITS

The compressor unit of domestic refrigerators and freezers is almost always the small hermetically sealed type. These units are not easily repaired, as most of the maintenance performed on them consists of removal and replacement. Figure 13-13 shows the procedures for removal.

Don't forget to pump down the system and equalize the suction and head pressure to the atmosphere, if applicable. Guard against spraying refrigerant on personnel. After replacement, the procedures given for removing air and moisture and recharging the system can be followed; however, the procedures may have to be modified because of the lack of some valves and connections. Follow the specific procedures contained in the manufacturer's manual.

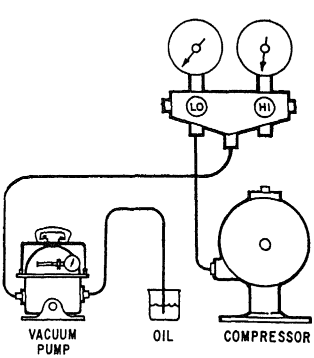
CHARGING A SYSTEM

One of your duties will be charging a system with refrigerant. If a system develops a leak, you must repair it first, then charge the system. Similarly, if a component of the system becomes faulty and must be replaced, some refrigerant will be lost and the system will require charging.

Before a system can be charged, all moisture and air must be eliminated from the components by drawing a vacuum on the system. To draw a vacuum on the system, connect the portable vacuum pump to the vacuum fitting on the refrigerant manifold test set (fig. 13-7), and connect the LO line to the suction service valve of the compressor, using appropriate connectors if required. Turn the suction service valve to midposition, so vacuum drags from the compressor crankcase and suction line back through the evaporator, expansion valve, and liquid line. When the receiver service valve, condenser service valve, and discharge service valve are open, the pump draws back through the receiver and condenser to the compressor.

Attach one end of a 1/4-inch copper tube in the vacuum pump discharge outlet. (See fig. 13-14.) Allow the vacuum pump to draw a vacuum of at least 25 inches. Submerge the other end of the copper tubing under 2 or 3 inches of clean compressor oil contained in a bottle. Continue to operate the vacuum pump until there are no more bubbles of air and vapor in the oil, which indicates that a deep vacuum has been obtained.

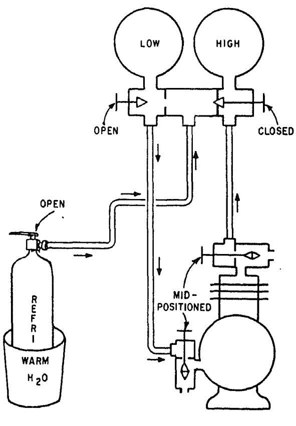
Maintain the deep vacuum operation for at least 5 minutes, then stop the vacuum pump. Leaking discharge valves of a vacuum pump cause oil to be sucked up into the copper discharge tube. Keep the vacuum pump off at least 15 minutes to allow air to enter the system through any leaks. Then, start the vacuum pump. A leaky system causes bubbling of the oil in the bottle. Examine and tighten any suspected joints in the line, including the line to the vacuum pump. Repeat the test.



54.344.1

Figure 13-14.—Connections for drawing a vacuum.

In most small refrigerating systems, low-side charging is generally recommended for adding refrigerant after repairs have been made. After the system has been cleaned and tested for leaks, it is charged in the following manner (fig. 13-15).



54.567

Figure 13-15.—Connections for low-side charging.

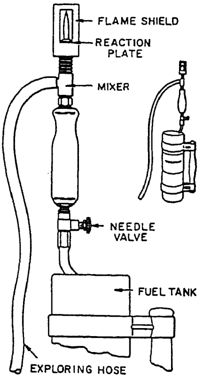
Connect a line from a refrigerant cylinder to the bottom center connection on the refrigerant manifold test set. Be certain the refrigerant cylinder is in a vertical position, so only refrigerant in the form of gas, not liquid, can enter the system. Leave the connection loose and crack the valve on the cylinder. This fills the line with gas and clears the air from the line. After clearing, tighten the connection.

Start the compressor and open the valve on the cylinder and the LO valve on the test set. Next, open the suction valve on the compressor to permit the gas to enter the compressor where it will be compressed and fed to the high side. Add the refrigerant slowly and check the liquid level indicator regularly until the system is fully charged. It is easy to check the receiver refrigerant level in some makes of condensing units because the receiver has minimum and maximum liquid level indicator valves which show the height of the liquid level when opened. If a liquid line sight glass is used, the proper charge may be determined when there is no bubbling of refrigerant as it passes by the glass. The sight glass will appear empty.

Again, be certain the refrigerant cylinder is in the vertical position at all times; otherwise, the liquid refrigerant will enter the compressor and, liquid not being compressible, damage the piston or other parts of the compressor.

TESTING FOR REFRIGERANT LEAKS

The best time to test joints and connections in a system is when there is enough pressure to increase the rate at which the refrigerant seeps from the leaking joint. There is usually enough pressure in the high-pressure side of the system; that is, in the condenser, receiver, and liquid line, including dehydrators, strainers, line valves, and solenoid valves. This is not necessarily true of the low-pressure side of the system, especially if it is a low-pressure installation, such as for frozen foods and ice cream, where pressures may run only slightly above zero on the gauge. When there is little pressure, increase the pressure in the low-pressure side of the system by bypassing the discharging pressure from the condenser to the low-pressure side through the service gauge manifold. Small leaks cannot be found unless the pressure inside the system is at least 40 to 50 psi, regardless of the method used to test for leaks.



47.105

Figure 13-16.—Halide leak detector.

Halide Leak Detector

The use of a halide leak detector is the most positive method of detecting leaks in a refrigerant system. Such a detector consists essentially of a torch burner, a copper reactor plate, and an exploring hose. (See fig. 13-16.)

Detectors use acetylene gas, alcohol, or butane as a fuel. Pressure for detectors that use alcohol is supplied by a pump. If a pump-pressure type of alcohol-burning detector is used, be sure that the air pumped into the fuel tank is pure.

Atmosphere suspected of containing R-12 vapor is drawn, by venturi action, through the exploring hose into the torch burner of the detector. Here the air passes over the copper reactor plate which is heated to incandescence. If there is a minute trace of R-12 present, the color of the torch flame changes from blue (neutral) to green as the R-12 contacts the reactor plate. The shade of green depends upon the amount of R-12; a pale green shows small concentrations and a darker green, heavier concentrations. Too much R-12 causes the flame to burn with a vivid purple color. Extreme concentrations of R-12 may extinguish the flame by crowding out the oxygen available from the air. A halide torch is so sensitive that it is useless when the atmosphere is contaminated by too much leakage of R-12. In testing for leaks of R-12, always start at the

highest point of the system and work towards the lowest point because R-12 is heavier than air.

When using a leak detector, you will obtain the best results by following the precautions listed below.

1. Be sure the reactor plate is properly in place.
2. Adjust the flame so it does not extend beyond the end of the burner. (A small flame is more sensitive than a large flame. If it is hard to light the torch when it is adjusted to produce a small flame, block the end of the exploring hose until the fuel ignites; then gradually open the hose.)
3. Clean out the exploring tube if the flame continues to have a white or yellow color. (A white or yellow flame is an indication that the exploring tube is partially blocked with dirt.)
4. Check to see that air is being drawn into the exploring tube; this check can be made from time to time by holding the end of the tube to your ear.
5. Hold the end of the exploring tube close to the joint being tested to prevent dilution of the sample by stray air currents.
6. Move the end of the exploring hose tube slowly and completely around each joint being tested. (Leak testing cannot be safely hurried. There is a definite time lag between the moment when air enters the exploring tube and the moment it reaches the reactor plate; permit enough time for the sample to reach the reactor plate.)
7. If a greenish flame is noted, repeat the test in the same area until the source of the refrigerant is located.

Always follow a definite procedure in testing for refrigerant leaks, so none of the joints are missed. Even the smallest leaks are important. However slight a leak may seem, it eventually empties the system of its charge and causes faulty operation. In the long run, the extra time spent in testing each joint will be justified. A refrigerant system should never be recharged until all leaks are discovered and repaired.

Electronic Leak Detector

The most sensitive leak detector of all is the electronic type. The principle of operation is based on the dielectric difference of gases. In operation, the gun is turned on and adjusted in a normal atmosphere. The leak detecting probe is then passed around the surfaces suspected of leaking. If there is a leak, no matter how tiny, the halogenated refrigerant is drawn into the probe. The leak gun then gives out a piercing sound, or a light flashes, or both, because the new gas changes the resistance in the circuit.

When using an electronic leak detector, minimize drafts by shutting off fans or other devices that cause air movement. Always position the sniffer below the suspected leak. Because refrigerant is heavier than air, it drifts downward. Always remove the plastic tip and clean it before each use. Avoid clogging it with dirt and lint. Move the tip slowly around the suspected leak.

Soap and Water Test

Soap and water may be used to test for leakage of refrigerant with a pressure higher than atmospheric pressure. Make a soap and water solution by mixing a lot of soap with water to a thick consistency. Let it stand until the bubbles have disappeared, and then apply it to the suspected leaking joint with a soft brush. Wait for bubbles to appear under the clear, thick, soap solution.

Find extremely small leaks by carefully examining suspected places with a strong light. If necessary, use a mirror to view the rear side of joints or other connections suspected of leaking.

MOTOR MAINTENANCE

Troubles with the electrical motors used to drive the compressors of mechanical refrigeration systems fall into two classes: mechanical and electrical. Electrical defects are covered later in this chapter.

Some compressors are belt-driven from the electrical motor (fig. 13-17). For proper operation, both the belt tension and pulley alignment adjustments must be made. Belt tension should be adjusted so a 1-pound force on the center of the belt, either up or down, does not depress it more than one-half inch. To adjust the alignment, loosen the setscrew on the motor pulley after tension adjustment is made. Be sure the pulley turns freely on the shaft; add a little oil if necessary. Turn the flywheel forward and backward several times. When it is correctly aligned, the pulley does not move inward or outward on the motor shaft. Tighten the setscrew holding the pulley to the shaft before starting the motor.

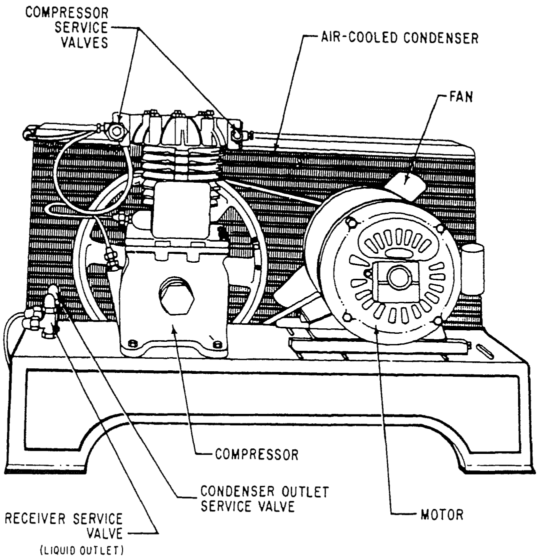


Figure 13-17.—Air-cooled condenser mounted on compressor unit.

Compressors may also be driven directly by a mechanical coupling between the motor and compressor shafts. Be sure the two shafts are positioned so they form a straight line with each other. The coupling on direct drive units should be realigned after repair or replacement. Clamp a dial indicator to the motor half coupling with its pointer against the outer edge of the compressor half coupling. Rotate the motor shaft, and observe any fluctuations of the indicator. Move the motor or compressor until the indicator is stationary when revolving the shaft one full turn. Secure the hold-down bolts, then recheck.

MOISTURE IN THE SYSTEM

When liquid refrigerant that contains moisture vaporizes, the moisture separates from the vapor. Because the vaporization of the refrigerant causes a cooling effect, the water that has separated can freeze. Most of the expansion and vaporization of the refrigerant occurs in the evaporator. However, a small amount of the liquid refrigerant vaporizes in the expansion valve, and the valve is cooled below the freezing point of water. As a result, ice can form in the expansion valve and interfere with its operation. If the needle in the valve freezes in a slightly off-seat position, the valve cannot permit the passage of enough refrigerant. If the needle freezes in a position far from the seat, the valve feeds too much refrigerant. In either case, precautions must be observed to assure a moisture-free system.

A dehydrator is filled with a chemical known as a desiccant, which absorbs moisture from the refrigerant passing through the dehydrator. Dehydrators are installed in the liquid line to absorb moisture in the system after original installation. An arrow on the dehydrator indicates the direction of flow. Desiccants are granular and are composed of silica gel, activated alumina, or calcium sulfate. Do not use calcium chloride or chemicals that form a nonfreezing solution. These solutions may react with moisture to form

undesirable substances, such as gums, sludges, or waxes. Follow the manufacturer's instructions as to limitations of dehydrators, as well as operation, recharging, replacing, and servicing.

LOOSE COPPER TUBING

In sealed units, loose copper tubing is usually detected by the sound of rattling or metallic vibration. The defect is usually eliminated by bending the tubing carefully to the position of least vibration. Do not touch it against other tubing or parts at a point of free movement, and do not change the tubing pitch or the tubing diameter by careless bending.

In open units, lengths of tubing must be well supported by conduit straps or other devices attached to walls, ceilings, or fixtures. Use friction tape pads to protect the copper tubing from the metal of the strap. When two tubes are together in a parallel position, vibration can be prevented by wrapping and binding them together with tape. When two lines are placed in contact for heat exchange, they should be soldered to prevent rattling and to permit better heat transfer.

DOORS AND HARDWARE

When hinges must be replaced, because of lack of lubrication or other reasons, the use of exact duplicates is preferable. Loose hinge pins must be securely braided. When thrust bearings are provided, they are held in place by a pin.

The latch or catch is usually adjusted for proper gasket compression. Shims or spacers may be added or removed for adjustment. Latch mechanisms should be lubricated and adjusted for easy operation. Latch rollers must not bind when operated. Be sure to provide sufficient clearance between the body of the latch and catch, so no contact is made. The only contact is made between the catch and the latch bolt or roller. These instructions also apply to safety door latches, when they are provided for opening the door from the inside, although it is locked from the outside.

Lack of complete gasket contact between the door overlap and the doorframe is usually caused by warping of the door. Correct the condition by installing a long, tapered wooden shim or splicer rigidly in place under the door seal. If this does not tighten the door to the frame, remove the door and either realign or rebuild it.

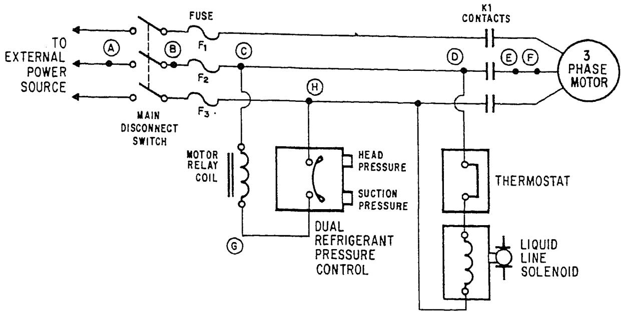
Repair or replace missing, worn, warped, or loose door gaskets. If the gasket is tacked on, rustproof tacks or staples should be used. If the gasket is clamped or held in place by the doorframe or the door panel, an exact replacement is necessary. In either case, the gasket should be installed so when the door is closed a complete and uniformly tight seal results. If doors freeze closed due to condensation and subsequent freezing, apply a light coat of glycerine on the gaskets.

DEFROSTING

Cooling units in the 35 °F to 45 °F refrigerators or cold storage rooms are generally defrosted automatically by setting the low-pressure control switch to a predetermined level. If this causes overload with consequent heavy frosting of the coil, manual defrosting is necessary. Cooling units of 35 °F and lower temperatures are defrosted manually. The most common method for manual defrosting is to spray water over the cooling coil; although warm air, electric heating, or hot gas refrigerant defrosts too. In any case, the fans must not be in operation during the defrosting. Defrost plate-type evaporator banks in below-freezing refrigerators when the ice has built up to a thickness of one-half inch, or when the temperature of the fixtures or the suction pressure is affected by the buildup of ice. Before removing frost from the plates, place a tarpaulin on the floor or over the contents of the refrigerator to catch the frost under the bank.

ELECTRICAL DEFECTS

The control systems for modern refrigeration systems are composed of many components that use or pass electrical power, including compressor drive motors, pressure switches, thermostats, and solenoid stop valves. Although as a Utilitiesman second class you are not responsible for troubleshooting these electrical components, you must be able to use the multimeter for locating opens, shorts, and grounds, and measuring voltage and current. Module 3 of the Navy Electricity and Electronics Training Series, NAVEDTRA 172-03-00-85, *(Introduction to Circuit Protection, Control, and Measurement),* will help you in learning to use electrical meters and testing equipment. When you have finished studying the module, return to this chapter and learn how to locate opens, shorts, and grounds in refrigeration control circuits.



54.347

Figure 13-18.—Simple refrigeration control system.

Opens

Figure 13-18 shows a simple refrigeration control system. You have learned the basics of electricity and how to use meters. Using this figure, you will put that knowledge to work. Remember one fact—if you are not sure what you are doing, call your supervisor or arrange for a Construction Electrician to assist you.

An "open" is defined as the condition of a component that prevents it from passing current. It may be a broken wire, a burned or pitted relay contact, a blown fuse, a broken relay coil, or a burned out coil winding. An open can be located in one of two ways. For the components in series, such as the main disconnect switch, fuses, the wire from Point C to Point D (fig. 13-18), the relay contacts, and the wire from Point E to Point F, a voltmeter should be used. Set up the voltmeter to measure the source voltage (120 volts ac, in this case). If the suspected component is open, the source will be measured across it. To check part of the main disconnect switch, close the switch and measure from Point A to Point B. If the meter reading is 0 volts, that part of the switch is good; if the voltage equals the source voltage, the switch is open. To check the fuse F_2, measure across it, Point B to Point C. Measuring across Points C and D or E and F will check the connecting wires for opens. One set of relay contacts can be checked by taking meter readings at Points D and E. These are just a few examples, but the rule of series components can always be applied. Remember, the three sets of contacts of relay K1 will not close unless voltage is present across the relay coil; the coil cannot be open or shorted. When testing an electrical circuit, follow the safe practices you have been taught and use procedures outlined in equipment manuals.

Opens in components that are in parallel cannot easily be found with a voltmeter because, as you know, parallel components have voltage across them at all times when the circuit is energized. In figure 13-18, the branch with the motor relay K1 and the dual refrigerant pressure control is considered a parallel circuit because when the main disconnect switch is closed and the fuses are good, there is voltage between Points C and H, regardless of whether the relay coil and pressure switch are open. To check for opens in these components, use an ohmmeter set at a low range. Disconnect all power by opening (and locking out, if possible) the main disconnect switch. This removes all power and ensures both personal and equipment safety. To check the motor relay K1 to see if its coil is open, put the ohmmeter leads on Points C and G. A reading near infinity (extremely high resistance) indicates an open. The contacts of the dual refrigerant pressure control can be tested by putting the ohmmeter leads from Point G to Point H. Again a reading near infinity indicates open contacts. You may need to consult the manufacturer's manual for the physical location of Points G and H. Notice the contacts of the control are normally

closed when neither the head pressure nor the suction pressure is above its set limits.

Shorts

Shorts are just the opposite of opens. Instead of preventing the flow of current, they allow too much current to flow, often blowing fuses. The ohmmeter on its lowest range is used to locate shorts by measuring the resistance across suspected components. If the coil of the motor relay K1 is suspected of being shorted, put the leads on Points C and G. A lower than normal reading (usually almost zero) indicates a short. You may have to determine the normal reading by consulting the manufacturer's manual or by measuring the resistance of the coil of a known good relay. If fuses F_2 and F_3 blow and you suspect a short between the middle and bottom lines (fig. 13-18), put the ohmmeter leads between Points C and H. Again, a low reading indicates a short. Remember, in all operations using an ohmmeter, it is imperative that all power be removed from the circuit for equipment and personal safety. Don't fail to do this!

Grounds

A ground is an accidental connection between a part of an electrical circuit and ground, due perhaps, to physical contact through wearing of insulation or movement. To locate a ground, follow the same procedure you used to locate a short. The earth itself, a cold water pipe, or the frame of a machine are all examples of ground points. To see whether a component is shorted to ground, put one ohmmeter lead on ground and the other on the point suspected to be grounded and follow the rules for locating a short. Be sure to turn off all power to the unit. It may even be wise to check for the presence of voltage first. Use a voltmeter set to the range suitable for measuring source voltage. If power does not exist, then use the ohmmeter.

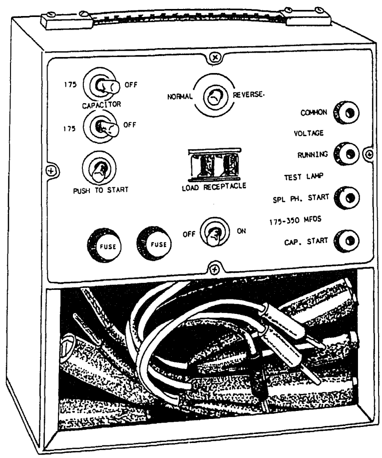
The limited amount of instruction presented here is not enough to qualify you as an electrician, but it should enable you to find such troubles as blown fuses, poor electrical connections, and the like. If the trouble appears more complicated than this, call your supervisor or ask for assistance from a Construction Electrician.

Testing the Motor

As a Utilitiesman, you should be able to make voltage measurements in a refrigeration system to ensure that the proper voltage is applied to the drive motor, as shown on the rating plate of the motor. If the proper voltage is applied (within 10 percent) to the terminals of the motor and yet it doesn't run, you must decide what to do. If it is an open system (not hermetically sealed), it is the Construction Electrician's job to repair the motor. If it is a hermetically sealed unit, however, you must use special test equipment to complete further tests and perhaps make the unit operational again.

If the unit doesn't run, it may be because the motor rotor or compressor crankshaft is stuck (remember, in a hermetically sealed unit, they are one and the same). If you apply electrical power to try and move the motor in the correct direction first and then reverse the power, you may be able to rock it free and not have to replace the unit. This is one of the purposes of the hermetic unit analyzer (fig. 13-19). To rock the rotor of an hermetically sealed unit, follow these steps:

1. Determine from the manufacturer's manual whether the motor is a split-phase or a capacitor-start type.
2. Remove any external wiring from the motor terminals.



54.348

Figure 13-19.—Hermetic unit analyzer.

3. Place the analyzer plugs in the jacks of the same color. If a split-phase motor is used, put the red plug in jack No. 3; if the capacitor-start motor is used, put the red plug in jack No. 4; and select a capacity value close to the old one with the toggle switches.

4. Connect the test clips as follows:

White to common

Black to the running winding

Red to the starting winding

5. Hold the push-to-start button down and at the same time move the handle of the rocker switch from normal to reverse. The frequency of rocking should not exceed five times within a 15-second period. If the motor starts, be certain that the rocker switch is in the normal position before releasing the push-to-start button.

More tests can be made with the hermetic unit analyzer, such as testing for continuity of windings and for grounded windings. Procedures for these tests are provided in the manual that comes with the analyzer. Generally, if the rocking procedure does not result in a free and running motor, the unit must be replaced.

TROUBLESHOOTING CHECKLIST

It is beyond the scope of this text to cover all of the troubles you may come across in working with refrigeration equipment. If you apply yourself, you can acquire a lot of additional information through on-the-job training and experience and by studying the manufacturer's instruction manuals.

First and foremost, safety must be stressed and safe operating practices followed, before and while doing any troubleshooting or service work. All local and national codes, as well as DoD rules concerning safety, must be observed. Some of the more important safety steps that are often overlooked are as follows:

1. Protective equipment, such as eye protection, gloves, hard hats, and so forth, must be available and worn.

2. Fire extinguishers must be readily available, in good working order, and adequate for the situation.

3. Safety tags with such notations as "Danger," "Hands Off," "Do Not Operate," and "Do Not Throw Switch" should be attached to valves, switches, and at other strategic locations when servicing or making repairs.

4. Install machinery guards properly before operating machinery.

The above is only a short list and not intended to be all inclusive. You will also find table 13-1, "Troubleshooting—Industrial Refrigeration," and table 13-2, "Troubleshooting Checklist—Domestic Refrigerators and Freezers," a useful guide in locating and correcting different troubles in refrigeration equipment.

Table 13-1.—Troubleshooting—Industrial Refrigeration

PROBLEM	POSSIBLE CAUSE	REMEDY OR COMMENT
I. Compressor will not start.	A. No power to motor.	1. Check power to and from fuses; replace fuses if necessary. 2. Check starter contacts, connections, overloads, and timer (if part winding start). Reset or repair as necessary. 3. Check power at motor terminals. 4. Repair wiring if damaged.
	B. Control circuit is open.	1. Safety switches are holding circuit open. Check high pressure, oil failure and low-pressure switches. Also check oil filter pressure differential switch if supplied. 2. Thermostat is satisfied. 3. Check control circuit fuses if blown; replace. 4. Check wiring for open circuit.

Vilter Manufacturing Corporation, Milwaukee, Wisconsin.

Table 13-1.—Troubleshooting—Industrial Refrigeration—Continued.

PROBLEM	POSSIBLE CAUSE	REMEDY OR COMMENT
II. Motor "hums" but does not start.	A. Low voltage to motor.	1. Check incoming power for correct voltage. Call power company or inspect/repair power wiring.
	B. Motor shorted.	1. Check at motor terminals. Repair or replace as necessary.
	C. Single-phase failure in the three-phase power supply.	1. Check power wiring circuit for component or fuse failure.
	D. Compressor is seized due to damage or liquid.	1. Remove belts or coupling. Manually turn crankshaft to check compressor.
	E. Compressor is not unloaded.	1. Check unloader system.
III. Compressor starts but motor cycles off on overloads.	A. Compressor has liquid or oil in cylinders.	1. Check compressor crankcase temperature. 2. Throttle suction stop valve on compressor to clear cylinders and act to prevent recurrence of liquid accumulation.
	B. Suction pressure is too high.	1. Unload compressor when starting. Use internal unloaders if present. 2. Install external bypass unloader.
	C. Motor control.	1. Motor control located in hot ambient. 2. Low voltage. 3. Motor overloads may be defective or weak. 4. Check motor control relay. 5. Adjust circuit breaker setting to full load amps.
	D. Bearings are "tight."	1. Check motor and compressor bearings for temperature. Lubricate motor bearings.
	E. Motor is running on single-phase power.	1. Check power lines, fuses, starter, motor, etc., to determine where open circuit has occurred.
IV. Compressor starts but short cycles automatically.	A. Low refrigerant charge.	1. Check and add if necessary.
	B. Driers plugged or saturated with moisture.	1. Replace cores.
	C. Refrigerant feed control is defective.	1. Repair or replace.
	D. No load.	1. To prevent short cycling, if objectionable, install pump-down circuit, anti-recycle timer or false load system.
	E. Unit is too large for load.	1. Reduce compressor speed. 2. Install false load system.
	F. Suction strainer blocked or restricted.	1. Check and clean or replace as necessary.
V. Motor is noisy or erratic.	A. Motor bearing failure or winding failure.	1. Check and repair as needed.
	B. If electronic starter, check calibration on control elements.	1. Adjust as necessary.
VI. Compressor runs continuously but does not keep up with the load.	A. Load is too high.	1. Speed up compressor or add compressor capacity. 2. Reduce load.
	B. Refrigerant metering device is underfeeding, causing the compressor to run at too low a suction pressure.	1. Check and repair liquid feed problems. 2. Check discharge pressure and increase if low.

Vilter Manufacturing Corporation, Milwaukee, Wisconsin.

Table 13-1.—Troubleshooting—Industrial Refrigeration—Continued.

PROBLEM	POSSIBLE CAUSE	REMEDY OR COMMENT
VI. Compressor runs continuously but does not keep up with the load—Continued.	C. Faulty control circuit, may be low-pressure control or capacity controls.	1. Check and repair.
	D. Compressor may have broken valve plates.	1. Check compressor for condition of parts. This condition can usually be detected by checking compressor discharge temperature.
	E. Thermostat control is defective and keeps unit running.	1. Check temperatures of product or space and compare with thermostat control. Replace or readjust thermostat.
	F. Defrost system on evaporator not working properly.	1. Check and repair as needed.
	G. Suction bags in strainers are dirty and restrict gas flow.	1. Clean or remove.
	H. Hot gas bypass or false load valve stuck.	1. Check and repair or replace.
VII. Compressor loses excessive amount of oil.	A. High suction superheat causes oil to vaporize.	1. Insulate suction lines. 2. Adjust expansion valves to proper superheat. 3. Install liquid injection (suction line desuperheating).
	B. Too low of an operating level in chiller will keep oil in vessel.	1. Raise liquid level in flooded evaporator (R12 systems only).
	C. Oil not returning from separator.	1. Make sure all valves are open. 2. Check float mechanism and clean orifice. 3. Check and clean return line.
	D. Oil separator is too small.	1. Check selection.
	E. Broken valves cause excessive heat in compressor and vaporization of oil.	1. Repair compressor.
	F. "Slugging" of compressor with liquid refrigerant that causes excessive foam in the crankcase.	1. "Dry up" suction gas to compressor by repairing evaporator. 2. Refrigerant feed controls are overfeeding. 3. Check suction trap level controls. 4. Install a refrigerant liquid transfer system to return liquid to high side.
VIII. Noisy compressor operation.	A. Loose flywheel or coupling.	1. Tighten.
	B. Coupling not properly aligned.	1. Check and align if required.
	C. Loose belts.	1. Align and tighten per specs. 2. Check sheave grooves.
	D. Poor foundation or mounting.	1. Tighten mounting bolts, grout base, or install heavier foundation.
	E. Check compressor with stethoscope if noise is internal.	1. Open, inspect, and repair as necesssary.
	F. Check for liquid or oil slugging.	1. Eliminate liquid from suction mains. 2. Check crankcase oil level.
IX. Low evaporator capacity.	A. Inadequate refrigerant feed to evaporators.	1. Clean strainers and driers. 2. Check expansion valve superheat setting. 3. Check for excessive pressure drop due to change in elevation, too small of lines (suction and liquid lines). A heat exchanger may correct this. 4. Check expansion valve size.

Vilter Manufacturing Corporation, Milwaukee, Wisconsin.

Table 13-1.—Troubleshooting—Industrial Refrigeration—Continued.

PROBLEM	POSSIBLE CAUSE	REMEDY OR COMMENT
IX. Low exaporator capacity—Continued.	B. Expansion valve bulb in a trap.	1. Change piping or bulb location to correct.
	C. Oil in evaporator.	1. Warm the evaporator, drain oil, and install an oil trap to collect oil.
	D. Evaporator surface fouled.	1. Clean.
	E. Air or product velocity is too low.	1. Increase to rated velocity. 2. Coils not properly defrosting. 3. Check defrost time. 4. Check method of defrost.
	F. Brine flow through evaporator may be restricted.	1. Chiller may be fouled or plugged. 2. Check circulating pumps. 3. Check process piping for restriction.
X. Discharge pressure too high.	A. Air in condenser.	1. Purge noncondensibles.
	B. Condenser tubes fouled.	1. Clean.
	C. Water flow is inadequate.	1. Check water supply and pump. 2. Check control valve. 3. Check water temperature.
	D. Airflow is restricted.	1. Check and clean: a. Coils b. Eliminators c. Dampers
	E. Liquid refrigerant backed up in condenser.	1. Find source of restriction and clear. 2. If system is overcharged, remove refrigerant as required. 3. Check to make sure equalizer (vent) line is properly installed and sized.
	F. Spray nozzles on evap condensers plugged.	1. Clean.
XI. Discharge pressure too low.	A. Ambient air is too cold.	1. Install a fan cycling control system.
	B. Water quantity not being regulated properly through condenser.	1. Install or repair water regulating valve.
	C. Refrigerant level low.	1. Check for liquid seal, add refrigerant if necessary.
	D. Evap condenser fan and water switches are improperly set.	1. Reset condenser controls.
XII. Suction pressure too low.	A. Light load condition.	1. Shut off some compressors. 2. Unload compressors. 3. Slow down RPM of compressor. 4. Check process flows.
	B. Short of refrigerant.	1. Add if necessary.
	C. Evaporators not getting enough refrigerant.	1. Discharge pressure too low. Increase to maintain adequate refrigerant flow. 2. Check liquid feed lines for adequate refrigerant supply. 3. Check liquid line driers.
	D. Refrigerant metering controls are too small.	1. Check superheat or liquid level and correct as indicated.
XIII. Suction pressure too high.	A. Low compressor capacity.	1. Check compressors for possible internal damage. 2. Check system load. 3. Add more compressor capacity.

Vilter Manufacturing Corporation, Milwaukee, Wisconsin.

Table 13-2.—Troubleshooting Checklist—Domestic Refrigerators and Freezers

Trouble	Possible causes	What to look for and what to do
1. Unit fails to start	Wiring	Loose connections, broken wires, grounded leads, open contacts, corroded contacts, blown fuses, poor plug contacts, poorly soldered connections. Correct defects found
	Low voltage	Rated voltage should be ± 10 percent. Overloaded circuits: read the voltage across the compressor-motor terminals; if it reads 100 volts or under, the circuit is overloaded. Check the voltage at the fuse panel; if this voltage is low, the power supply voltage needs correction. Provide a separate circuit for the unit
	Compressor motor	Remove leads from the compressor motor. Apply 115 volts to the motor running winding terminals on the terminal plate from a separate two-conductor cable. Then, touch a jumper wire across both the starting and the running winding terminals. If the motor starts and runs, the trouble is isolated in the control or in the compressor motor thermostat. If the unit does not start, replace it
	Motor thermostat	Connect a jumper to shunt the thermostat from the line-side terminal of the thermostat across to the common terminal of the compressor motor. If the unit starts, the thermostat is open and should be replaced. Do not attempt to correct calibration of the thermostat. Replace the thermostat
2. Unit runs normally but temperature is too high	Temperature selector control set too high	Reset the dial to its normal position
	Temperature control out of adjustment	Readjust in accordance with the manufacturer's instructions
	Poor air circulation in the cabinet	Paper on shelves; too much food in storage; other obstructions to proper air circulation. Maintain sufficient space in the cabinet for proper air circulation
	Damper control faulty	On models with this type of control it is best to replace the control or to follow the manufacturer's instructions
3. Unit runs normally but temperature is too low	Temperature selector control out of adjustment	Reset the control to a higher position
	Temperature control out of adjustment	Readjust the control in accordance with the manufacturer's instructions
	Unit placed in cold location	If possible, remove the unit to a location where the ambient temperature is 55 degrees F. or over
	Temperature control bulb improperly located	Relocate the bulb in accordance with the manufacturer's instructions
	Damper open too far	Close the damper to restrict the air circulation in the cabinet, on units so equipped. Instruct the user on this point
4. Unit runs too long and temperature is too low	Temperature bulb improperly located or defective	Replace or relocate the bulb in accordance with the manufacturer's instructions. Be sure the bulb is securely attached to the evaporator. Replace defective bulbs
	Compressor	Refer to item 7

Table 13-2.—Troubleshooting Checklist—Domestic Refrigerators and Freezers—Continued

Trouble	Possible causes	What to look for and what to do
5. Unit does not run and temperature is too high	No power at outlet	Check the fuses, and replace burned-out ones
	Poor plug contact	Spread the plug contacts
	Control in "Off" position	Turn to the "Coldest" position, then back to the "Normal" position
	Temperature control inoperative	Examine the control main contacts; clean them with a magneto file or with fine sandpaper; replace them if they are badly burned or pitted. Do not use emery cloth. Check and replace the relay assembly, if necessary. If the temperature control main contacts are found open, try warming the temperature control bulb by hand. If this does not close the control contacts, the control bellows has lost its charge, and the control should be replaced
	Pressures in system not equalized	Wait for a period of about 5 minutes before trying to restart the unit. See item 3
	Open circuit in wiring	Make voltmeter or test-lamp checks to determine whether any part of the electrical wiring system is open, or any controls are inoperative. Correct defective connections, and replace worn or damaged controls
	Compressor thermostat open	See item 1
	Open motor windings	See item 1
6. Units runs for short periods; temperature too high	Defrosting heater	On a unit equipped with a defrosting heater, check the defrosting cycle in accordance with the manufacturer's instructions. Ascertain whether the defrosting heater is turned off by making sure that no current flows through it during the refrigerating cycle
	Unit operates on thermostat	See item 9
7. Unit runs continuously; temperature too high	Moisture, obstruction, or restriction in liquid line	Before checking for moisture, be certain that the symptoms observed are not caused by improper operation of the defrosting heater, if so equipped. These heaters are wired into the cabinet wiring so that the control contacts short out the heaters when the contacts are closed. Thus the heaters are on only when the machine is off, when the control contacts open, and when the evaporator is on the defrost cycle. Check the control contacts to see that the defrosting heaters are off when the machine is running. At high ambient temperature, the unit will cycle on its thermostat. The evaporator will warm up over its entire surface if the liquid circulation is completely obstructed. If it is only partly obstructed, a part of the frost on the evaporator will melt. Under these conditions, the unit will probably operate noisily, and the motor will tend to draw a heavy current. If the liquid line is obstructed by ice, this ice will melt after the unit has warmed up. The unit will then refrigerate normally. If this obstruction occurs too frequently and spare units are available, replace the unit
	Broken valves	Exceedingly high current to the motor. No cooling in the evaporator and no heating in the condenser. Excessive compressor noise. Replace the hermetic compressor or replace the valves in an open-type compressor
	Clogged tubing	Check the tubing for damage, sharp bends, kinks, pinches, etc. Straighten the tubing, if possible, or replace the unit

Table 13-2.—Troubleshooting Checklist—Domestic Refrigerators and Freezers—Continued

Trouble	Possible causes	What to look for and what to do
7. Unit runs continuously; temperature too high—Continued	Refrigerant leaks or undercharged	The unit may tend to run normally but more frequently. The evaporator becomes only partly covered with frost. The frost will tend to build up nearest to the capillary tube while the section nearest to the suction line will be free from frost. As leakage continues, the frostline will move back across the evaporator. When the refrigerant is entirely gone, no refrigeration will occur. Units with large evaporators will not frost up unless the evaporator is mounted inside of the box. Test for leaks with a halide leak detector. Recharge the unit, if necessary
	Cabinet light	Check the operation of the light switch, see that the light goes out as the door is closed
	Air circulation	See that sufficient space is allowed for air circulation. Relocate or reposition the unit, if possible
	Evaporator needs defrosting	Advise the user on defrosting instructions
	Gasket seals	Give them a thorough cleaning. If worn, they should be replaced
	Ambient temperature	Relocate the unit in a location where the ambient temperature ranges from 55 degrees to 95 degrees F.
	Defroster heater	On units so equipped, check the defoster heater circuit. See item 6
	Compressor suction valve sticks open or is obstructed by corrosion or dirt	Ascertain whether the condenser gets warm, and check the current drawn by the motor. If the condenser does not get warm and the current drawn is low, disassemble the compressor (open type) and check the action of the suction valve
	Compressor discharge valve sticks open or is obstructed	Connect the test gauge assembly, run the unit until the low-side pressure is normal. With an ear in close proximity to the compressor, listen for a hissing sound of escaping gas past the discharge valve. The low-side pressure gauge will rise, and the high side will drop equally until both are the same. Clean out obstructions
8. Unit runs too long; temperature too high	Condenser	Check for any obstruction in the path of air circulation around the condenser. Clean any dust accumulation
	Fan	On units so equipped, check to see that the fan blades are free to turn and that the fan motor operates
	Door seal	Clean seals around the door. Check closure of the door with a strip of paper between the gasket and the cabinet at all points around the door. The gasket should grip the paper tightly at all points
	Refrigerant	Check for leakage and undercharge of the refrigerant. See item 7
	User	Warn the user against too frequent opening of the door, storage of hot foods, heavy freezing loads, and other improper usage
9. Unit operates on thermostat; temperature too high	Voltage	Check voltage ± 10 percent of rating
	Defrosting heater	See that the defrosting heater is turned off
	Starting relay	Determine that the starting relay does not stick closed. Follow the manufacturer's instructions on methods of checking
	Condenser	Check the air circulation around the condenser; also check the operation of the fan

Table 13-2.—Troubleshooting Checklist—Domestic Refrigerators and Freezers—Continued

Trouble	Possible causes	What to look for and what to do
9. Unit operates on thermostat; temperature too high—Continued	Pressures not equalized	Wait 5 minutes after stopping, then restart; turn to the coldest position, then to the normal position
	Restrictions in liquid line	See item 7
	Thermostat	Thermostat may be out of calibration. Replace the thermostat
10. Noisy operation	Fan blades	If the blades are bent, realign them, and remove any obstructions. If the blades are so badly bent or warped that they cannot be realigned, they should be replaced
	Fan motor	Check the motor mounting and tighten the connections
	Tube rattling	Adjust the tubes so that they do not rub together
	Food shelves	Adjust them to fit tightly
	Compressor	Malfunctioning valves; loose bolted connections; improper alignment of open-type compressor. Replace the hermetic compressor; tighten the connections; realign the open-type compressor
	Floor or walls	Check to see that the floor is rigid, and whether the walls vibrate. Locate and correct any such sources of noise. Make corrections by bolting or nailing loose portions to structural members
	Belt	Check the condition of the motor belt. Replace it when it becomes worn or frayed
11. Unit uses too much electricity	Door	Check the door seal. See item 7
	Usage	Instruct the user on proper usage of the motor. See item 8. Check the overload
	Ambient temperature too high	See item 7. The unit will operate more frequently and over longer periods of time in a high-temperature atmosphere. Correct, if possible, by changing the location of the unit
	Defrost control	Check the defrost circuit according to the manufacturer's instructions
	Temperature control	Selector control dial set too low. Advise the user. Operate it as near to the "Normal" setting as possible
12. Stained ice trays	Poor cleaning procedures	Use soap and warm water to wash trays. Rinse them thoroughly. Do not use metal sponges, steel wool, or coarse cleaning powders

DOMESTIC REFRIGERATORS AND FREEZERS

Domestic refrigerators and home freezer units contain up to 16 cubic feet of storage space. They are used by the Navy in quarters or hospital diet kitchens for food storage, in laboratories for preservation of biological specimens and serums, and for similar purposes elsewhere. They are entirely self-contained units. The evaporator is in the insulated storage compartment, and the condenser is in a separate uninsulated compartment. All parts and compartments are housed in one cabinet, and the assembly of the unit is always done at the factory. No unusual installation procedures are involved, and units may be installed by activity personnel.

A domestic refrigerator should be placed in the coolest and most convenient location, away from the rays of the sun, and near a source of

power. Place the refrigerator away from the wall about 2 to 3 inches to provide sufficient ventilation for the condensing unit. You may work with both conventional and combination refrigerators.

Conventional refrigerators have a single evaporator to maintain low temperatures for frozen food and ice cube storage and, by means of an insulated baffle, to operate the food storage compartment at temperatures above freezing.

Combination refrigerators have separate freezer and food compartments. The freezer may have a separate door, and its size may be 60 to 100 percent of the volume of the food compartment. The temperature of the freezer is held near 0 °F, and in the fresh food compartment, the evaporator maintains temperatures varying from 35 °F to 40 °F. Each compartment may be cooled by its own compressor, or a single evaporative arrangement may be used for both compartments. The operation is entirely automatic.

Home freezers provide storage space with temperatures of 0 °F and lower, as well as a fast-freezing zone where limited quantities of fast food may be frozen in a reasonably short time with minimum effects upon the temperatures of food already stored.

The Utilitiesman must be able to perform various duties in the maintenance and repair of domestic refrigerators and home freezers at Navy activities. This section provides information to aid you in handling some of the more common types of troubles. But let us remind you that the information given here is intended as a general guide and should, therefore, be used with the manufacturer's detailed instructions.

MANUFACTURER'S WARRANTIES

Whenever major repairs or replacements are required, maintenance personnel should determine whether the warranty period, during which the refrigerator is guaranteed by the manufacturer, has expired. This is particularly important with regard to sealed components, factory-calibrated automatic temperature controls, and other factory-guaranteed parts. If activity maintenance personnel try to adjust these components, it can cancel the warranty.

NORMAL OPERATION

Troubleshooting of any type of refrigeration unit depends, in part, on your ability to compare normal operation with that obtained from the unit being operated. The left-hand column of table 13-2 lists the observable faults, such as the unit fails to run, the temperature is too high or too low, the unit runs continuously or too long, or operation is too noisy. Obviously, for you to detect these abnormal operations, you must first know what normal operation is.

Climate affects running time. A refrigeration unit generally operates more efficiently in a dry climate. In an ambient temperature of 75 °F, the running period usually approximates 2 to 4 minutes, and the off period, 12 to 20 minutes. By connecting a self-starting clock to the motor terminals, you can verify the length of each of these periods. If the on-off periods are appreciably different from the times mentioned above, you should consult the trouble chart for corrective action or for the next step in narrowing down the location of the fault.

REFERENCES

Troubleshooting Chart Basic Guide for Diagnosing and Correcting Industrial Refrigeration Service Problems, Vilter Manufacturing Corp., Milwaukee, Wisc., 1987.

Trane Air-Conditioning Manual, The Trane Co., La Crosse, Wisc., 1986.

CHAPTER 14

AIR CONDITIONING

Learning Objective: Recognize the characteristics and procedures required to service and troubleshoot air-conditioning systems.

"Air conditioning" is defined as the simultaneous control of temperature, humidity, air movement, and the quality of air in a conditioned space or building. The intended use of the conditioned space is the determining factor for the temperature, humidity, air movement, and quality of air to be maintained. Air conditioning is able to provide widely varying atmospheric conditions: from those necessary for drying telephone cables to those necessary for cotton spinning. Air conditioning can maintain any atmospheric condition regardless of variations in outdoor weather.

In this chapter several aspects of air conditioning are discussed; for example, heat pumps, chilled-water systems, periodic maintenance, cooling towers, troubleshooting, and automotive air conditioning.

AIR CONDITIONING

A complete air-conditioning system includes a means of refrigeration, one or more heat transfer units, air filters, a means of air distribution, an arrangement for piping the refrigerant and heating medium, and controls to regulate the proper capacity of these components.

The items outlined above are considered to be the components of a complete air-conditioning system. In addition, the application and design requirements, that an air-conditioning system must meet, make it necessary to arrange some of these components to condition the air in a certain sequence. For example, an installation that requires reheating of the conditioned air must be arranged with the reheating coil on the downstream side of the dehumidifying coil; otherwise, reheating of the cooled and dehumidified air is impossible.

There has been a tendency by many designers to classify an air-conditioning system by referring to one of its components. For example, the air-conditioning system in a building may include a dual duct arrangement to distribute the conditioned air and is then referred to as a dual duct system. This classification makes no reference to the type of refrigeration, the piping arrangement, or the type of controls.

For the purpose of classification, the following definitions are used:

An air-conditioning unit is understood to consist of a heat transfer surface for heating and cooling, a fan for air circulation, a means of cleaning the air, a motor, a drive, and a casing.

A self-contained air-conditioning unit is understood to be an air-conditioning unit that is complete with compressor, condenser, controls, and a casing.

An air-handling unit consists of a fan, heat transfer surface, and a casing.

A remote air-handling unit or a remote air-conditioning unit is a unit located outside of the conditioned space which it serves.

HEAT PUMPS

A heat pump removes heat from one place and puts it into another. A domestic refrigerator is a heat pump in that it removes heat from inside a box and releases it on the outside. The only difference between a refrigerator and a residential or commercial heat pump is that the latter can reverse its system. The heat pump is one of the most modern means of heating and cooling known. Using no fuel, the electric heat pump

automatically heats or cools as determined by outside temperature. The air type of unit works on the principle of removing heat from the atmosphere. No matter how cold the weather, some heat can always be extracted and pumped indoors to provide warmth. This cycle is merely reversed with the unit removing heat from the area to be cooled and exhausting it to the outside to cool during the hot months. The heat pump is designed to control the moisture in the air and to remove dust and pollen. Cool air provided during hot weather enters with uncomfortable moisture removed. In winter, when a natural atmosphere is desirable, air is not dried out when pumped indoors.

The heat pump is simple in operation (fig. 14-1). In summer, the evaporator is cooling and the condenser outside is giving off heat the evaporator picked up. In winter, the condenser outside is picking up heat from the outside air because its temperature is lower than that of the outside air (until it reaches the balance point). This heat is then sent to the evaporator by the compressor and is given off into the conditioned space. A reversing valve is the key to this operation. The compressor always pumps in one direction, so the reversing valve changes the hot-gas direction from the condenser to the evaporator as indicated by the setting on the thermostat. The setting of the thermostat assures the operator of a constant temperature through an automatic change from heating to cooling anytime outside conditions warrant. Heat pumps are made not only for small homes but large homes and commercial buildings as well. The heat pump does not require an equipment room, and its minor noise is discharged into the atmosphere. The remote heat pump has only a blower and evaporator, which can be installed under the floor, in an attic, or other out-of-the-way location, depending on the application and its requirements. Supplemental heat can be added into the duct and set to come on by a second stage of the thermostat, an outside thermoset, or both, depending on design of the system.

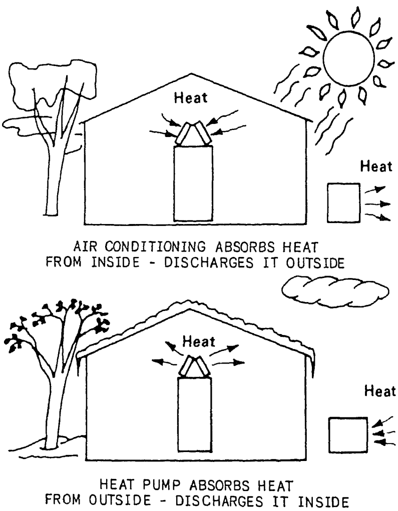


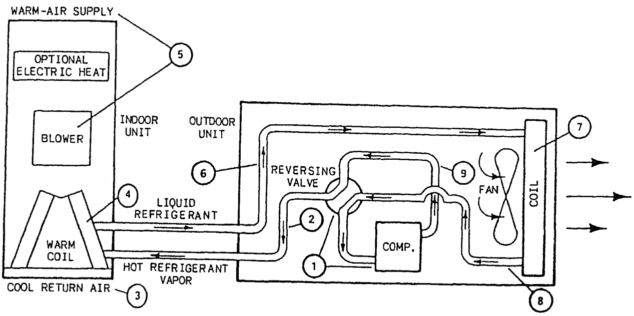
Figure 14-1.—Basic heat pump operation.

Heating Refrigerant Cycle

The thermostats initial heating demand starts the compressor. The reversing valve is de-energized during the heating mode. The compressor pumps the hot refrigerant gas through the indoor coil where heat is released into the indoor airstream. This warmed supply air is distributed through the conditioned space. As the refrigerant releases its heat, it changes into a liquid which is then transported to the outdoor coil. The outdoor coil absorbs heat from the air blown across the coil by the outdoor fan. The refrigerant changes from a liquid into a vapor as it passes through the outdoor coil. The vapor returns to the compressor where it increases temperature and pressure. The hot refrigerant is then pumped back to the indoor coil to start another cycle. (See fig. 14-2.)

Cooling Refrigerant Cycle

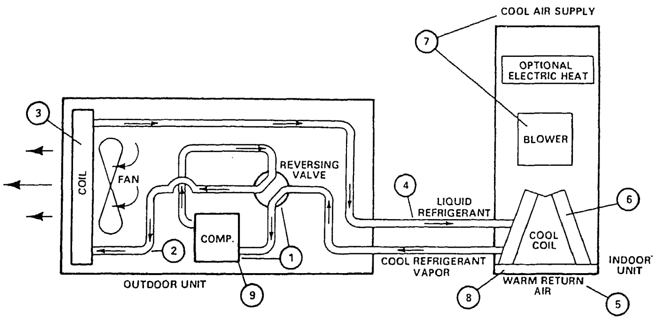
Once the thermostat is put in the cooling mode, the reversing valve is energized. A cooling demand starts the compressor. The compressor pumps hot, high-pressure gas to the outdoor coil where heat is released by the outdoor fan. The refrigerant changes into a liquid which is transported to the indoor blower. The refrigerant absorbs heat from the indoor air of the supply air which is distributed throughout the controlled space. This temperature change removes moisture from the air and forms condensate which must be piped away. The compressor suction pressure draws the cool vapor back into the compressor where the temperature and pressure are greatly increased. This completes the cooling refrigerant cycle. (See fig. 14-3.)



1. THE COMPRESSOR IS ENERGIZED WHILE THE REVERSING VALVE REMAINS DE-ENERGIZED.
2. THE COMPRESSOR PUMPS HOT REFRIGERANT GAS TO THE INDOOR COIL.
3. COOL RETURN AIR IS DRAWN OVER THE INDOOR COIL BY THE BLOWER.
4. THE REFRIGERANT RELEASES ITS HEAT INTO THE RETURN AIRSTREAM AND CONSEQUENTLY TURNS INTO A LIQUID.
5. THE WARMED SUPPLY AIR IS DISTRIBUTED THROUGHOUT THE CONTROLLED SPACE.
6. THE LIQUID REFRIGERANT IS TRANSPORTED TO THE OUTDOOR COIL.
7. THE REFRIGERANT ABSORBS HEAT FROM THE OUTDOOR AIR THAT IS BLOWN ACROSS THE COIL BY THE FAN.
8. THE REFRIGERANT TURNS INTO A COOL VAPOR WHICH IS DRAWN BACK TO THE COMPRESSOR.
9. THE COMPRESSOR INCREASES THE PRESSURE OF THE REFRIGERANT. THE HOT REFRIGERANT IS THEN PUMPED BACK TO THE INDOOR COIL TO START ANOTHER CYCLE.

54.612X

Figure 14-2.—Heating cycle.



1. THE REVERSING VALVE AND COMPRESSOR ARE ENERGIZED.
2. THE COMPRESSOR PUMPS HOT REFRIGERANT GAS TO THE OUTDOOR COIL.
3. THE FAN DISSIPATES HEAT FROM THE REFRIGERANT AND CHANGES IT INTO A LIQUID.
4. THE LIQUID REFRIGERANT IS SENT ON TO THE INDOOR COIL.
5. WARM AIR IS DRAWN OVER THE INDOOR COIL BY THE BLOWER.
6. THE REFRIGERANT ABSORBS HEAT FROM THE INDOOR AIR AND CHANGES INTO A COOL VAPOR.
7. THIS LOWERS THE TEMPERATURE OF THE SUPPLY AIR WHICH IS DISTRIBUTED THROUGHOUT THE CONTROLLED SPACE.
8. THIS TEMPERATURE CHANGE WILL REMOVE MOISTURE FROM THE AIR AND FORM CONDENSATE WHICH MUST BE PIPED AWAY.
9. THE COMPRESSOR SUCTION PRESSURE DRAWS THE REFRIGERANT BACK INTO THE COMPRESSOR WHERE ITS PRESSURE IS GREATLY INCREASED. THIS COMPLETES ONE COOLING REFRIGERANT CYCLE.

54.613X

Figure 14-3.—Cooling cycle.

Defrost Cycle

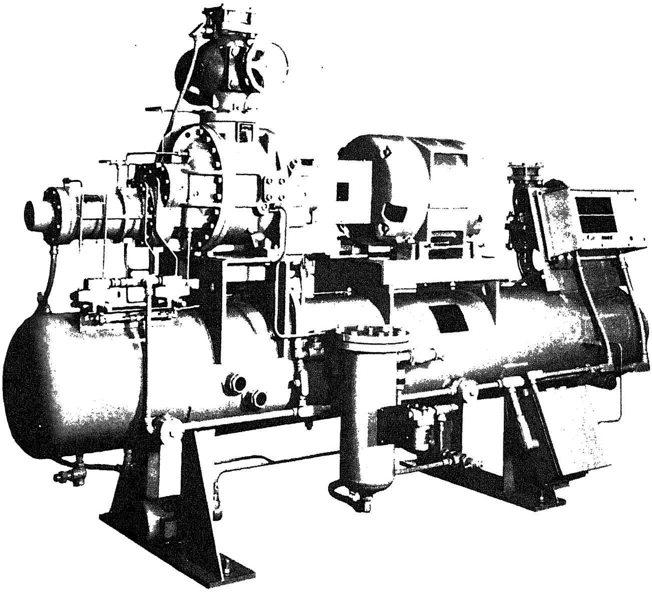
Heat pumps operating at temperatures below 45 °F accumulate frost or ice on the outdoor coil. The relative humidity and ambient temperature affect the degree of accumulation. This ice buildup restricts the airflow through the outdoor coil which consequently affects the system operating pressures. The defrost control detects this restriction and switches the unit into a defrost mode to melt the ice.

The reversing valve is energized and the machine temporarily goes into the cooling cycle where hot refrigerant flows to the outdoor coil. The outdoor fan stops at the same time, thus allowing the discharge temperature to increase rapidly to shorten the length of the defrost cycle. If there is supplemental heat, a defrost relay activates it to offset the cooling released by the indoor coil.

Supplemental Heat

As the outside temperature drops, the heat pump runs for longer periods until it eventually operates continually to satisfy the thermostat. The system "balance point" is where the heat pump capacity exactly matches the heating loss. The balance point varies between homes, depending on actual heat loss and the heat pump capacity. However, the balance point usually ranges between 15 °F and 40 °F. Either electric heat or fossil fuels provide the auxiliary heat.

Conventional heat pump applications use electric heaters downstream from the indoor coil.



Credit Frick Company

54.614X

Figure 14-4.—Rotary screw compressor unit.

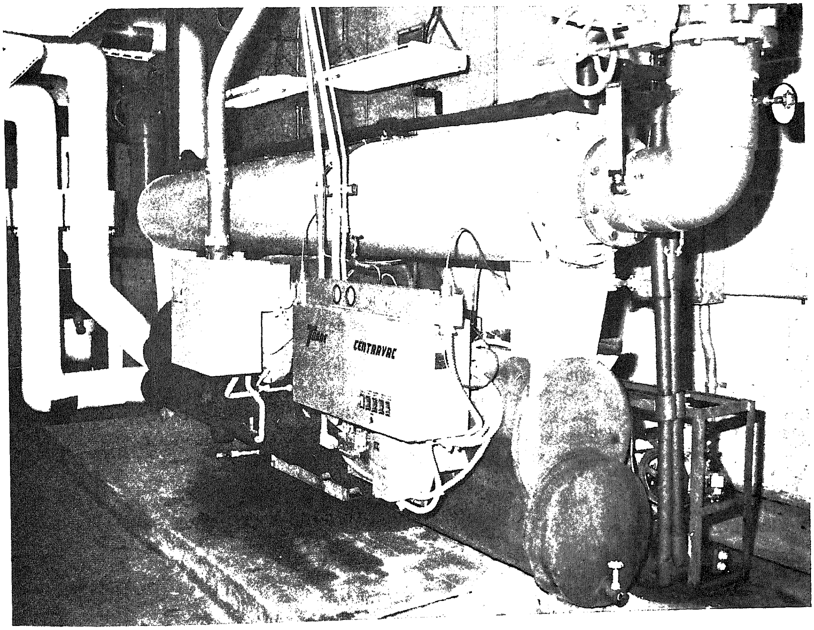
This prevents damaging head pressures when the heat pump and auxiliary heat run simultaneously. The indoor coil can only be installed downstream from the auxiliary heat if a "fuelmaster" control system is used. This control package uses a two-stage heat thermostat with the first stage controlling heat pump operation and the second stage controlling furnace operation.

CHILLED-WATER SYSTEMS

Water chillers (figs. 14-4 and 14-5) are used in air conditioning for large tonnage capacities and for central refrigeration plants serving a number of zones, each with its individual air-cooling and air-circulating units. An example is a large hospital with wings off a corridor. Air conditioning may be necessary in operating rooms, treatment suites, and possibly some recovery wards. Chilled water-producing and water-circulating equipment is in a mechanical equipment room. Long mains with many joints between condensing equipment and conditioning units increase the chance of leaks. Expensive refrigerant has to be replaced. It may be better to provide water-cooling equipment close to the condensing units and to circulate chilled water to remote air-cooling coils. Chilled water is circulated to various room-located coils by a pump, and the temperature of the air leaving each coil may be controlled by a thermostat that controls a water valve or stops and starts each cooling coil fan motor.

Types of Coolers

The two most commonly used water coolers for chilled water air conditioning are flooded shell-and-tube and dry-expansion coolers. The disadvantage of the flooded shell-and-tube cooler



54.615

Figure 14-5.—Two-stage semi-hermetic centrifugal. NOTE: This unit is very narrow.

is that it needs more refrigeration for equal size systems. Futhermore, water in tubes may freeze and split tubes when the load falls off.

Controls

Flooded coolers should be controlled with a low-pressure float control—a float valve placed so the float is about the same level as the predetermined refrigerant level. The float, as a pilot, moves a valve in the liquid line to control the flow of refrigerant to the evaporator. Dry-expansion coolers are controlled by liquid expansion valves. The refrigerant is inside the tubes. Freezing of water on the tubes is less likely to damage it.

Condensers

The primary purpose of the condenser is to liquefy the refrigerant vapor. The heat added to the refrigerant in the evaporator and compressor must be transferred to some other medium from the condenser. This medium is the air or water used to cool the condenser.

WATER-COOLED CONDENSERS.—Condensing water must be noncorrosive, clean, inexpensive, below a certain maximum temperature, and available in sufficient quantity. The use of corrosive or dirty water results in high maintenance costs for condensers and piping. Dirty water, as from a river, can generally be economically filtered if it is noncorrosive; corrosive water can sometimes be economically treated to neutralize its corrosive properties if it is clean. An inexpensive source of water that must be filtered and chemically treated will probably not be economical to use without some means of conservation, such as an evaporative condenser or a cooling tower.

Water circulated in evaporative condensers and cooling towers must always be treated to reduce the formation of scale, algae, and chalky deposits. Overtreatment of water, however, can waste costly chemicals and result in just as much maintenance as undertreatment.

SHELL-AND-COIL CONDENSERS.—A shell-and-coil condenser is simply a continuous copper coil mounted inside a steel shell. Water flows through the coil, and the refrigerant vapor from the compressor is discharged inside the shell to condense on the outside of the cold tubes. In many designs, the shell also serves as a liquid receiver.

The shell-and-coil condenser has a low manufacturing cost but this is offset by the disadvantage that this type of condenser is difficult to service in the field. If a leak develops in the coil, the head from the shell must be removed and the entire coil pulled from the shell to find and repair the leak. A continuous coil is a nuisance to clean, whereas straight tubes are easy to clean with mechanical tube cleaners. Thus, with some types of cooling water, it may be difficult to maintain a high rate of heat transfer with a shell-and-coil condenser.

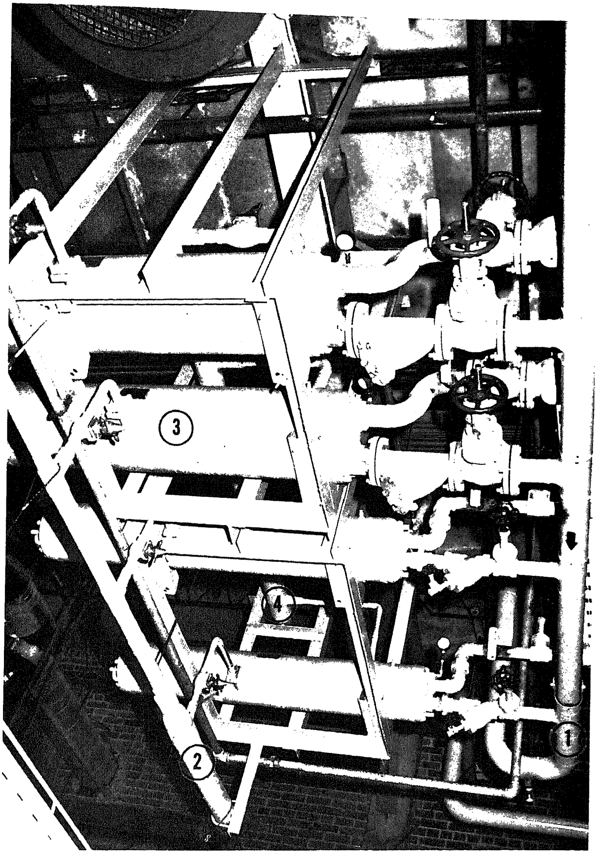
SHELL-AND-TUBE CONDENSERS.—The shell-and-tube condenser shown in figure 14-6 permits a large amount of condensing surface to be installed in a comparatively small space. The condenser consists of a large number of 3/4- or 5/8-inch tubes installed inside a steel shell. The water flows inside the tubes while the vapor flows outside around the nest of tubes. The vapor condenses on the outside surface of the tubes and drips to the bottom of the condenser, which may be used as a receiver for the storage of liquid refrigerant. Shell-and-tube condensers are used for practically all water-cooled refrigeration systems.

To obtain a high rate of heat transfer through the surface of a condenser, it is necessary for the water to pass through the tubes at a fairly high velocity. For this reason, the tubes in shell-and-tube condensers are separated into several groups—the same water traveling in series through each of these various groups. A condenser having four groups of tubes is known as a four-pass condenser because the water flows back and forth along its length four times. Four-pass condensers are common although any reasonable number of passes may be used. The fewer the number of water passes in a condenser, the greater the number of tubes in each pass.

The friction of water flowing through a condenser with a few passes is lower than in one having a large number of passes. This means a lower power cost in pumping the water through a condenser with a smaller number of passes.

AIR CONDENSERS.—The use of dry air for condensing purposes is gaining in popularity. It now is being used in applications where the single-unit load ranges beyond 50 tons. The primary reasons for its popularity are as follows:

1. Air is readily available and there is no disposal problem.
2. First, cost is lower than other condensing means involving water conservation.



1. Entering water.
2. Liquid line to receiver.
3. Condenser.
4. Hot-gas header from compressor.

54.161

Figure 14-6.—Paralleled water-cooled condensers, overhead view.

3. Maintenance costs are reduced.

There are offsetting disadvantages that must be evaluated, such as the following:

1. Large volumes of air are required which may cause noise problems.

2. Operating costs are high because the power to drive the compressor at or near full load is high.

3. The air condenser increases in capacity when the system load falls off, creating operating problems at part load.

4. Start-up problems are encountered at low outdoor temperatures.

Nothing can be done to overcome the first two disadvantages. The part load problem has had various solutions, such as multispeed fan motors to vary the airflow over the condenser coil and thus its capacity. This is a costly and unsatisfactory solution because it is impossible to reduce the air quantity sufficiently. Multilouvered dampers over the condenser coil are less expensive than multispeed motors and provide a greater air quantity reduction that more nearly follows the capacity variation to a point.

The modern air condenser is available with either propeller or centrifugal type fans for moving the air through the condenser coil. When the air condenser can be installed out of doors, the propeller fan type of unit is generally used. If for some reason the condenser is to be installed indoors with ductwork to carry the air to and from the unit, the condenser with the centrifugal fan is more suitable. Either type of unit can be built with a liquid subcooling circuit.

An air condenser generally will be located on the roof of the structure being served. This is true in the case of buildings with flat roofs. If the roof is pitched, the air condenser will have to be located on the ground adjacent to the building.

When you are selecting the location of the air condenser, consideration must be given to its relationship to walls or other obstructions. It is necessary and important that both the inlet and the outlet from the unit not be blocked or restricted in any manner. An air condenser should never be located in a light well of a building when the discharge air cannot move freely away from the unit. If a unit must be located near a wall, it should be installed with the inlet air side of the unit toward the wall and the discharge away from the wall. Sufficient distance must be allowed between the wall and the unit, so the airflow is not restricted. A good rule of thumb with a propeller type of unit is to allow 1 foot of distance between the extreme back of the unit and the obstruction for each foot of fan radius.

CLEANING WATER-COOLED CONDENSERS

You may be assigned to some activities where water-cooled condensers are used in the air-conditioning system. So, the Utilitiesman will probably have the job of cleaning the condensers. Information that assists you in cleaning water-cooled condensers is presented below.

Water contains many impurities—the content of which varies in different localities. Lime and iron are especially injurious; they form a hard scale on the walls of water tubes that reduces the efficiency of the condenser. Condensers can be cleaned mechanically or chemically.

Scale on tube walls of condensers with removable heads is removed by attaching a round steel brush to a rod and by working it in and out of the tubes. After the tubes have been cleaned with a brush, flush them by running water through them. Some scale deposits are harder to remove than others, and a steel brush may not do the job. Several types of tube cleaners for removing hard scale can usually be purchased from local sources. Be sure that the type selected does not injure water tubes.

The simplest method of removing scale and dirt from condenser tubes not accessible for mechanical cleaning is by using inhibited acid to clean coils or tubes through chemical action. Figure 14-7 shows the connections and the equipment for cleaning the condenser with an inhibited acid, both when the acid flows by gravity (top view) and when forced circulation is used (bottom view). When scale deposit is not great, gravity flow of the acid provides enough cleaning. When the deposit almost clogs the tubes, forced circulation should be used. Prevent chemical solution from splashing in your eyes and on your skin or clothing.

Equipment and connections for circulating inhibited acid through the condenser using gravity flow, as shown in figure 14-7, are as follows:

1. A rubber or plastic bucket for mixing solution. Do not use galvanized materials because prolonged contact with acid deteriorates such surfaces.
2. A crock or wooden bucket for catching the drainage residue.
3. One-inch steel pipe that is long enough to make connections shown.
4. Fittings for 1-inch steel pipe. The vent pipe shown should be installed at the higher connection of the condenser.

Equipment and connections for circulating inhibited acid through the condenser using forced circulation, as shown in figure 14-7, are as follows:

1. A pump suitable for this application. A centrifugal pump and a 1/2-horsepower motor is

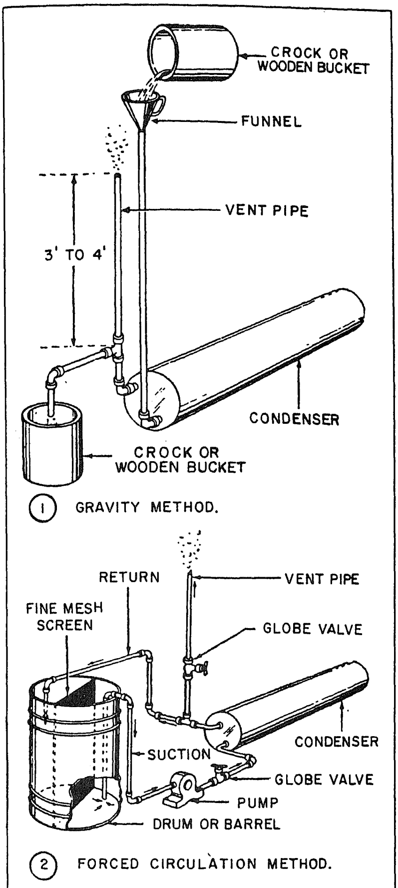


Figure 14-7.—Cleaning water-cooled condensers with acid solution.

recommended (30 gallons per minute at 35-foot head capacity).

2. A non-galvanized metal tank, stone, or porcelain crock, or wooden barrel with a capacity of about 50 gallons, with ordinary bronze or copper screening to keep large pieces of scale or dirt from getting into the pump intakes.

3. One-inch pipe that is long enough to make the piping connections shown.

4. Fittings for 1-inch steel globe valves. The vent pipe, as shown, should be installed at the higher connection of the condenser.

Handle the inhibited acid for cleaning condensers with the usual precautions observed when handling acids. It stains hands and clothing and attacks concrete. If the inhibitor is not present, it attacks steel. Therefore, use every precaution to prevent spilling or splashing. When splashing might occur, cover the surfaces with burlap or boards. Gas produced during cleaning that escapes through the vent pipe is not harmful; but, prevent any liquid or spray from being carried through with the gas. The basic formula should be maintained as closely as possible, but a variation of 5 percent is permissible. The inhibited acid solution is made up of the following:

1. Water.
2. Commercial hydrochloric (muriatic) acid with specific gravity of 1.19. Eleven quarts of acid should be used for each 10 gallons of water.
3. Three and two-fifths ounces of inhibitor powder for each 10 gallons of water used.
4. Place the required amount of water in a non-galvanized metal tank or wooden barrel, and add the necessary amount of inhibitor powder while stirring the water. Continue stirring the water until the powder is completely dissolved, then add the required quantity of acid. NEVER add water to acid; this may cause an explosion.

In charging the system with an acid solution, when GRAVITY FLOW is used, introduce the inhibited acid, as shown in figure 14-7. Do not add the solution faster than the vent can exhaust the gases generated during cleaning. When the condenser has been filled, allow the solution to remain overnight.

When FORCED CIRCULATION is used, the valve in the vent pipe should be fully opened while the solution is introduced into the condenser but must be closed when the condenser is completely charged and the solution is circulated by the pump. When a centrifugal pump is used, the valve in the supply line may be fully closed while the pump is running.

The solution should be allowed to stand or be circulated in the system overnight for cleaning out average scale deposits. The cleaning time also depends on the size of the condenser to be cleaned. For extremely heavy deposits, forced circulation is recommended, and the time should be increased

to 24 hours. The solution acts more rapidly if it is warm, but the cleaning action is just as thorough with a cold solution if adequate time is allowed.

After the solution has been allowed to stand or has been circulated through the condenser the required time, it should be drained and the condenser thoroughly flushed with water. To clean condensers with removable heads by using inhibited acid, use the above procedure without removing the heads. However, extra precaution must be exercised in flushing out the condenser with clear water after the acid has been circulated through the condenser to ensure acid removal from all water passages.

MAINTENANCE

A well-planned maintenance program avoids unnecessary downtime and prolongs the life of the unit and reduces the possibility of costly equipment failure. It is recommended that a maintenance log be maintained, recording the maintenance activities. This provides a valuable guide and aids in obtaining economies and length of service from the unit. This section describes specific maintenance procedures which must be performed as a part of the maintenance program of the unit. Use and follow the manufacturer's manual for the unit you are to do maintenance on. When specific directions or requirements are furnished, follow them. Before performing any of these operations, however, be sure that power to the unit is disconnected unless otherwise instructed.

WARNING: When maintenance checks and procedures must be completed with the electrical power on, care must be taken to avoid contact with energized components or moving parts. Failure to exercise caution when working with electrically powered equipment may result in serious injury or death.

Coil Cleaning

Refrigerant coils must be cleaned at least once a year, or more frequently if the unit is located in a dirty environment. This helps maintain unit operating efficiency and reliability. The relationship between regular coil maintenance and efficient/reliable unit operation is outlined below.

1. Clean condenser coils minimize compressor head pressure and amperage draw, and promote system efficiency.
2. Clean evaporator coils minimize water carry-over and help eliminate frosting and/or compressor flood-back problems.
3. Clean coils minimize required fan brake horsepower and maximize efficiency by keeping coil static pressure loss at a minimum.
4. Clean coils keep motor temperature and system pressure within safe operating limits for good reliability.

Specific instructions for cleaning condenser coils are provided in the following paragraphs. Follow these instructions as closely as possible to avoid potential damage to the coils.

The following equipment is required to clean condenser coils: a soft brush and either a garden pump-up sprayer or a high-pressure sprayer. In addition, a high-quality detergent must be used. Follow the manufacturer's recommendations for mixing to make sure the detergent is alkaline with a pH value less than 8.5.

1. Disconnect the power to the unit.

WARNING: Open the unit disconnect switch. Failure to disconnect the unit from the electrical power source may result in severe electrical shock and possible injury or death.

2. Remove enough panels from the unit to gain access to the coil.
3. Protect all electrical devices, such as motors and controllers, from dust and spray.
4. Straighten coil fins with a fin rake, if necessary.
5. Use a soft brush to remove loose dirt and debris from both sides of the coil.
6. Mix the detergent with water according to the manufacturer's instructions. The detergent and water solution may be heated to a maximum of 150°F to improve its cleaning ability.

WARNING: Do not heat the detergent and water solution to temperatures in excess of 150°F. High-temperature liquids sprayed on the coil exterior raise the pressure within the coil and may cause it to burst, resulting in possible injury and equipment damage.

7. Place the detergent and water solution in the sprayer. If a high-pressure sprayer is used, be sure to follow these guidelines:

- Minimum nozzle spray angle is 15 degrees.
- Spray the solution perpendicular (at a 90 degree angle) to the coil face.
- Keep the sprayer nozzle at least 6 inches from the coil.
- Sprayer pressure must not exceed 600 psi.

CAUTION: Do not spray motors or other electrical components. Moisture can cause component failure.

8. Spray the side of the coil where the air leaves first, then spray the other side (where the air enters). Allow the detergent and water solution to stand on the coil for 5 minutes.
9. Rinse both sides of the coil with cool, clean water.
10. Inspect the coil. If it still appears to be dirty, repeat Steps 8 and 9.
11. Remove the protective covers installed in Step 3.
12. Replace all unit panels and parts, and restore electrical power to the unit.

Fan Motors

Inspect periodically for excessive vibration or temperature. Operating conditions vary the frequency of inspection and lubrication. Motor lubrication instructions are found on the motor tag or nameplate. If not available, contact the motor manufacturer for instructions.

To relubricate the motor, complete the following:

WARNING: Disconnect the power source for motor lubrication. Failure to do so may result in injury or death from electrical shock or moving parts.

1. Turn the motor off. Make sure it cannot accidentally restart.
2. Remove the relief plug and clean out any hardened grease.
3. Add fresh grease through the fitting with a low-pressure grease gun.
4. Run the motor for a few minutes to expel any excess grease through the relief vent.
5. Stop the motor and replace the relief plug.

Fan Bearing Lubrication

Fan bearings with grease fittings or with grease line extensions should be lubricated with a lithium-base grease that is free of chemical impurities. Improper lubrication can result in early bearing failure. To lubricate the fan bearings, complete the following:

1. Lubricate the bearings while the unit is not running; disconnect the main power switch.
2. Connect a manual grease gun to the grease line or fitting.
3. Add grease, preferably when the bearing is warm, while turning the fan wheel manually until a light bead of grease appears at the bearing grease seal.

Filters

Always install filters with directional arrows pointing toward the fans.

To clean permanent filters, wash under a stream of hot water to remove dirt and lint. Follow with a wash of mild alkali solution to remove old filter oil. Rinse thoroughly and let dry. Recoat both sides of the filter with filter oil and let dry. Replace the filter element in the unit.

PERIODIC MAINTENANCE

Perform all of the indicated maintenance procedures at the intervals scheduled. This prolongs the life of the unit and reduces the possibility of costly equipment failure and downtime. A checklist should be prepared which lists the required service operations and the times at which they are to be performed. The following is a sample of such a list.

Weekly

1. Check the compressor oil level. If low, allow the compressor to operate continually at full load for 3 to 4 hours; check the oil level at 30 minute intervals. If the level remains low, add oil.
2. Observe the oil pressure. The oil pressure gauge reading should be approximately 20 to 35 psi above the suction pressure gauge reading.
3. Stop the compressor and check the shaft seal for excessive oil leakage. If found, check the seal with a refrigerant leak detector (open compressor only).
4. Check the condition of the air filters and air-handling equipment. Clean or replace filters, as necessary.
5. Check the general operating conditions, system pressures, refrigerant sight glass, and so forth.

Monthly

(Repeat Items 1 through 5)

6. Lubricate the fan and motor bearings, as necessary. Obtain and follow the manufacturer's lubricant specifications and bearing care instructions.
7. Check the fan belt tension and alignment.
8. Tighten all fan sheaves and pulleys. If found to be loose, check alignment before tightening.
9. Check the condition of the condensing equipment. Observe the condition of the condenser coil in the air-cooled condenser. Clean,

as necessary. Check the cooling tower water in the water-cooled condenser. If algae or scaling is evident, water treatment is needed. Clean the sump strainer screen of the cooling tower.

Annually

(Repeat Items 1 through 9)

10. Drain all circuits of the water-condensing system. Inspect the condenser piping and clean any scale or sludge from the tubes of the condenser.

11. If a cooling tower or evaporative condenser is used, flush the pumps and sump tank. Remove any rust or corrosion from the metal surfaces and repaint.

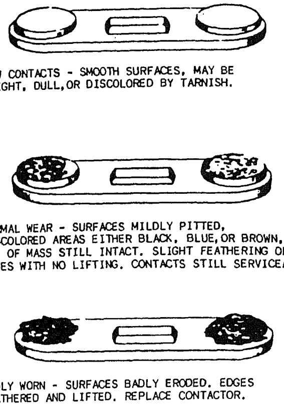
12. Inspect all motor and fan shaft bearings for signs of wear. Check the shafts for proper end-play adjustment.

13. Replace worn or frayed fan belts.

14. Clean all water strainers.

15. Check the condition of the ductwork.

16. Check the condition of the electrical contacts of all contactors, starters, and controls. Remove the condensing unit control box cover and inspect the panel wiring. All electrical connections should be secure. Inspect the compressor and condenser fan motor contactors. If the contacts appear severely burned or pitted, replace the contactor (fig. 14-8). Do not clean the contacts. Inspect the condenser fan capacitors for visible damage.



Reprinted by permission of the Trane Company.

54.617X

Figure 14-8.—Compressor contactor replacement guide.

Seasonal Shutdown

In preparation for seasonal shutdown, it is advisable to pump down the system and valve off the bulk of the refrigerant charge in the condenser. This minimizes the quantity of refrigerant that might be lost due to any minor leak on the low-pressure side of the system and, in the case of the open compressor, refrigerant that might leak through the shaft seal.

(Hermetic Compressor Pump Down)

1. Close the liquid line shutoff valve at the condenser and start the system. When the suction pressure drops to the cutout setting of the low-pressure control, the compressor stops.

2. Open the compressor electrical disconnect switch to prevent the compressor from restarting, and then front seat the compressor discharge and suction valves.

(Open Compressor Pump Down)

1. If the system is not equipped with gauges, install a pressure gauge in the back-seat port of the compressor suction valve. Crack the valve off the backseat.

2. Close the liquid line shutoff valve at the condenser.

3. Manually open the liquid line solenoid valve(s). If the valves do not have manual opening devices, lower the setting of the system temperature controller so the valves are held open during the pump down.

4. Install a jumper wire across the terminals of the low-pressure switch. Since the system suction pressure is to be pumped down below the cutout setting of the low-pressure switch, the jumper is necessary to keep the compressor running.

5. Start the compressor. Watching the suction pressure gauge, stop the compressor by opening its electrical disconnect switch when the gauge reading reaches 2 psig.

6. Front seat the compressor discharge valve.

CAUTION: Do not allow the compressor to pump the suction pressure into a vacuum. A slight positive pressure is necessary to prevent air and moisture from being drawn into the system through minor leaks and through the now unmoving shaft seal.

7. Remove the jumper wire from the low-pressure control.

8. Remove the gauge from the port of the suction valve; replace the port plug and front seat the valve.

(All Systems)

1. Using a refrigerant leak detector, check the condenser and liquid receiver, if used, for refrigerant leaks.

2. Valve off the supply and return water connections of the water-cooled condenser. Allow the condenser to remain full of water during the off season. A drained condenser shell is more likely to rust and corrode than one full of water. If the condenser will be subjected to freezing temperatures, drain the water and refill it with an antifreeze solution.

3. Drain the cooling tower or evaporative condenser, if used; flush the sump and paint any rusted or corroded areas.

4. Open the system master disconnect switch and padlock it in the open position.

Seasonal Start-up

1. Perform all annual maintenance on the air-handling system and other related equipment.

2. Fill the water sump of the cooling tower or evaporative condenser, if used.

3. Open the shutoff valves of the water-cooled condenser.

4. Make certain the liquid line solenoid valve(s) is on automatic control.

5. Open the liquid line shutoff valve.

6. Back seat the compressor suction and discharge valves.

7. Close the system master electrical disconnect switch.

8. Start the system.

9. After the system has operated for 15 to 20 minutes, check the compressor oil level sight glass, oil pressure, and the liquid line sight glass. If satisfactory, readjust the system temperature controller to the proper temperature setting.

SAFETY MEASURES

Toxic or flammable refrigerants are seldom used in comfort air-conditioning systems. Anhydrous ammonia is toxic and flammable, and methyl chloride refrigerant is moderately so; therefore, neither of these should be used for comfort air conditioning. Most modern units use R-12 or R-22 refrigerants that are not toxic except when decomposed by a flame. If the liquefied refrigerant contacts the eyes, the person suffering the injury must be taken to a doctor at once.

As first-aid treatment, avoid rubbing or irritating the eyes, and put drops of sterile mineral oil into them as an irrigative agent. The eyes must then be washed, if irritation continues, with a weak boric acid solution or a sterile salt solution not to exceed 2 percent of ordinary table salt. Should the skin come in contact with the liquefied refrigerant, the skin is to be treated as though it had been frostbitten or frozen. "Frostbite" is a term applied to the effect of extreme cold on any part of the body. Severe freezing of the deeper tissues is dangerous and often results in gangrene. A frostbitten area is unnaturally white and feels numb. The area should be treated to restore the circulation and normal warmth of the affected area. The treatment must not be too vigorous. Rubbing the frostbite with snow or ice was a method long in use but is now considered dangerous because it is likely to remove the skin and damage local tissue. Rapid thawing in warm water has become the accepted treatment for frostbite. Time is crucial and the sooner the tissues are warmed, the better the result. Irreparable damage may occur when the extremities are frozen for several hours. For a quick thaw, place the frostbitten areas in water of approximately 110°F. This is as warm as many people can stand. The thawing skin becomes red and warm; it burns, aches, or throbs. But once the area has thawed, there is no need to warm it further. Dry the skin and lie flat in bed with the extremities exposed to the warm air of the room or cover them with flannel or cotton, and protect them from injury. Treat the damaged tissues gently and avoid walking if possible. Consult a physician, because additional measures may be essential to avoid gangrene.

Do not adjust, clean, lubricate, or service any parts of equipment that are in motion. Ensure that moving parts, such as pulleys, belts, or flywheels, are fully enclosed with proper guards attached.

Before making repairs, open all electric switches controlling the equipment. Tag and lock the switches to prevent short circuits or accidental starting of equipment. When moisture and brine are on the floor, fatal grounding through the body is possible when exposed electrical connections can be reached or touched by personnel. De-energize electrical lines before repairing them, and ground all electrical tools.

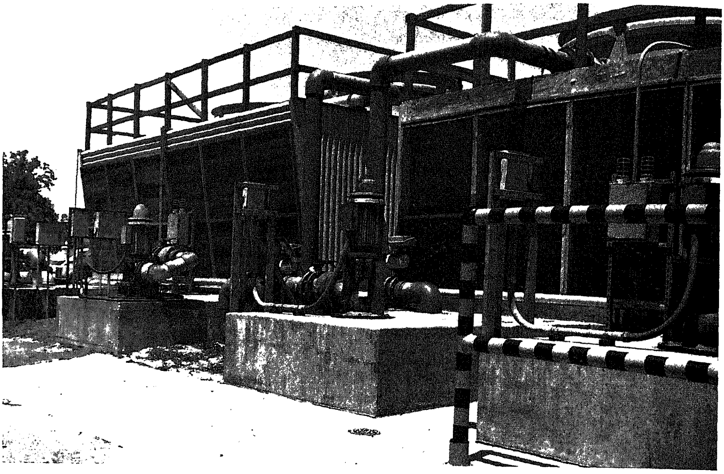


Figure 14-9.—Built-up towers with submersible pumps and concrete sumps. 54.618

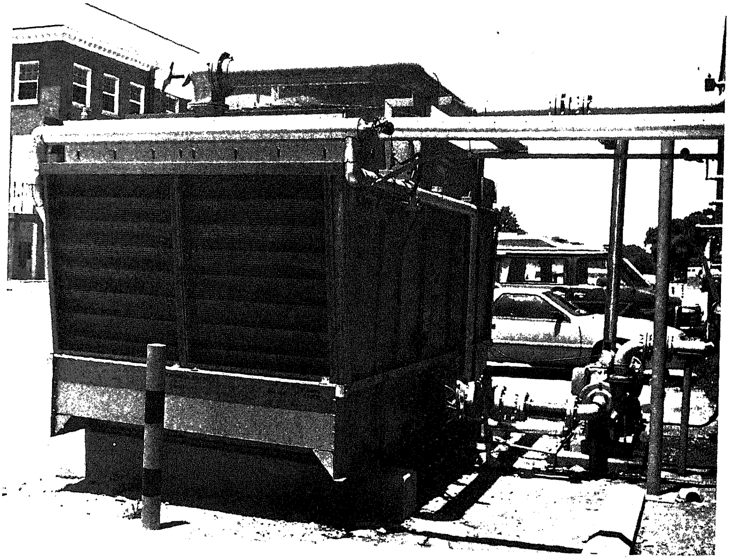


Figure 14-10.—A package tower with a remote, variable-speed pump. 54.619

COOLING TOWERS

Cooling towers are classified according to the method of moving air through the tower as natural draft, induced draft, or forced draft. (See figs. 14-9 through 14-11.)

NATURAL DRAFT

The natural draft cooling tower is designed to cool water by means of air moving through the tower at the low velocities prevalent in open spaces during the summer. Natural draft towers are constructed of cypress or redwood and have numerous wooden decks of splash bars installed at regular intervals from the bottom to the top. Warm water from the condenser is flooded or sprayed over the distributing deck and flows by gravity to the water-collecting basin.

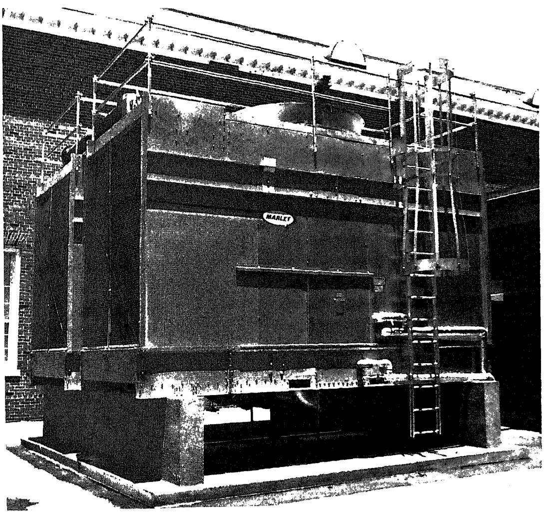
A completely open space is required for the natural draft tower since its performance depends on existing air currents. Ordinarily, a roof is an excellent location. Louvers must be placed on all sides of a natural draft tower to reduce drift loss.

Important design considerations are the wind velocity and the height of the tower. A wind velocity of 3 miles per hour is generally used for design of natural draft cooling towers. The natural draft cooling tower was once the standard design for cooling condenser water in refrigeration systems up to about 75 tons. It is now rarely selected unless low initial cost and minimum power requirements are primary considerations. The drift loss and space requirements are much greater than for other cooling tower designs.

INDUCED DRAFT

An induced draft cooling tower is provided with a top-mounted fan that induces atmospheric air to flow up through the tower, as warm water falls downward. An induced draft tower may have only spray nozzles for water backup, or it may be filled with various slat and deck arrangements. There are several types of induced draft cooling towers.

In a counterflow induced draft tower, a top-mounted fan induces air to enter all four sides of the tower and to flow vertically upward as the water cascades through the tower. The counterflow tower is particularly well adapted to a restricted space as the discharge air is directed vertically upward, and the four sides require only minimum clearance for air intake area. The primary breakup of water may be either by



54.620

Figure 14-11.—Paralleled package towers.

pressure spray or by gravity from pressure-filled flumes.

A double-flow induced draft tower has a top-mounted fan to induce air to flow across the fill material. The air is then turned vertically in the center of the tower. The distinguishing characteristics of a double-flow induced draft tower are the two air intakes on opposite sides of the tower and the horizontal flow of air through the fill sections.

Comparing counterflow and double-flow induced draft towers of equal capacity, the double-flow tower is somewhat wider but the height is much less. Cooling towers must be braced against the wind. From a structural standpoint, therefore, it is much easier to design a double-flow than a counterflow tower as the low silhouette of the double-flow type offers much less resistance to the force of the winds.

Mechanical equipment for counterflow and double-flow towers is mounted on top of the tower and is readily accessible for inspection and maintenance. The water-distributing systems are completely open on top of the tower and can be inspected during operation. This makes it possible to adjust the float valves and clean stopped-up nozzles while the towers are operating.

The cross-flow induced draft tower is a modified version of the double-flow induced draft tower. The fan in a cross-flow cooling tower draws air through a single horizontal opening at one end and discharges the air at the opposite end.

The cooling tower is a packaged tower that is inexpensive to manufacture and is extremely popular for small installations. As a packaged cooling tower with piping and wiring in place, it is simple to install and may be placed wherever there is a clearance of 2 feet for the intake end and a space of 10 feet or more in front of the fan. The discharge end must not face the prevailing wind and should not be directed into a traffic area as drift loss may be objectionable.

In some situations, an indoor location for the cooling tower may be desirable. An induced draft tower, of the counterflow or cross-flow design, is generally selected for indoor installation. Two connections to the outside are usually required: one for drawing outdoor air into the tower and the other for discharging it back to the outside. A centrifugal blower is often necessary for this application to overcome the static pressure of the ductwork. Many options are possible as to the point of air entrance and air discharge. This flexibility is often important in designing an indoor installation. Primary water breakup is by pressure spray and fill of various types.

The induced draft cooling tower, for indoor installation, is a completely assembled packaged unit but is so designed that it can be partially disassembled to permit passage through limited entrances. Indoor installations of cooling towers are becoming more popular. External space restrictions, architectural compatibility, convenience for observation and maintenance all combine to favor an indoor location. The installation cost is somewhat higher than an outdoor location. Packaged towers are available in capacities to serve the cooling requirements of refrigeration plants in the 5- to 75-ton range.

FORCED DRAFT

A forced draft cooling tower uses a fan to force air into the tower. In the usual installation, the fan shaft is in a horizontal plane. The air is forced horizontally through the fill and upward to be discharged out the top of the tower.

Underflow cooling towers are an improved design of the forced draft tower that retains all the advantages of the efficient double-flow design. Air is forced into the center of the tower at the bottom. The air is then turned horizontally (both right and left) through fill chambers and is discharged vertically at both ends. By forcing the air to flow upward and outward through the fill and leave at the ends, operating noise is baffled and a desirable reduction of sound level is achieved. All sides of the underflow tower are smoothly encased with no louver openings. This blends with modern architecture and eliminates the necessity of masonry walls or other screening devices oftentimes necessary to conceal cooling towers of other types.

MATERIALS

Redwood has been the standard construction material for cooling towers for many years. Though cypress, as well as treated fir and pine, has been used occasionally, these materials have not enjoyed a wide application. Casings are constructed of laminated waterproof plywood. Such casings, as well as other noncorrosive materials at critical points, are essential in areas having a highly corrosive atmosphere. Nails, bolts, and nuts of copper or aluminum are almost standard practice for cooling tower construction.

Cooling towers of metal coated with plastic or bituminous materials have met with only limited success, principally because of the high maintenance cost as compared with wood towers. Air intake louvers and fill are redwood.

Packaged towers with metal sides and wood fill are reasonably common. Sheet aluminum has been used for siding for limited periods of time by some manufacturers. Plastic slats have been used for fill material but have not proved satisfactory in all cases.

Fire ordinances of a large city may require that no wood be used in construction of cooling towers. With steel or some other fireproof casing and without fill, a cooling tower will comply with the most restrictive ordinances.

MAINTENANCE

Water treatment is an important part of the operation of a cooling tower. The evaporation of water from a cooling tower leaves certain solids behind—the same sort as the lime in a tea kettle. Recirculation of the water in the condenser cooling tower circuit, and the accompanying evaporation, causes the concentration of solids to increase. The concentration must be controlled or scale and corrosion will result.

Though draining the system from time to time and refilling with fresh water is one method of control, it is not recommended. Soon after refilling, the dissolved solids again build up to a dangerous concentration. A more common practice is to waste a certain amount of water continually from the system to the sewer. The water wasted is called blowdown. Blowdown is sometimes accomplished by wasting sump water through an overflow. A better practice, however, is to bleed the required quantity of blowdown from the warm water leaving the condenser on its way to the cooling tower. A mineral salt buildup (calcium bicarbonate concentration) of 10 grains per gallon is considered the maximum allowable concentration for untreated water in the sump if serious corrosion and scaling difficulties are to be avoided.

Theoretically, the evaporation rate is 1.0 percent of the water supplied to the tower for every 10 degrees the water is cooled. The highest evaporation rate occurs when the tower is used for the longest range and in the hottest weather. An assumed evaporation rate of 0.8 percent of the inlet water flow for every 10 degrees of cooling is a reasonable approximation for the great majority of atmospheric conditions.

In many instances, the makeup water contains dissolved salts in excess of 10 grains per gallon. It is obvious, then, that even 100 percent blowdown will not maintain a sump concentration of 10 grains. If the blowdown alone cannot maintain satisfactory control, then chemicals should be used.

Makeup water for a cooling tower is the sum of drift loss, evaporation, and blowdown. The drift loss for mechanical draft towers ranges from 0.1 percent of the total water being cooled for the better designs to as much as 0.3 percent. In estimating makeup water for a cooling tower, the higher value of 0.3 percent for drift loss is suggested. If the drift loss is actually less than this, the excess makeup water supplied is merely wasted down the overflow. This does, in effect, increase the amount of blowdown and is favorable from the viewpoint that the concentration of scale-forming compounds in the tower sump will be somewhat lower.

Redwood, even though it is a highly durable material, is not immune to deterioration. The type of deterioration varies with the nature of the environmental conditions to which the wood is exposed. The principal types of deterioration are leaching, delignification, and microbiological attack.

Algae and slime are present in water and must be controlled chemically or the rate of heat transfer in the condenser will be materially reduced. Condenser tubing, cooling tower piping, and metal surfaces in the water-circulating system must be protected from scale and corrosion.

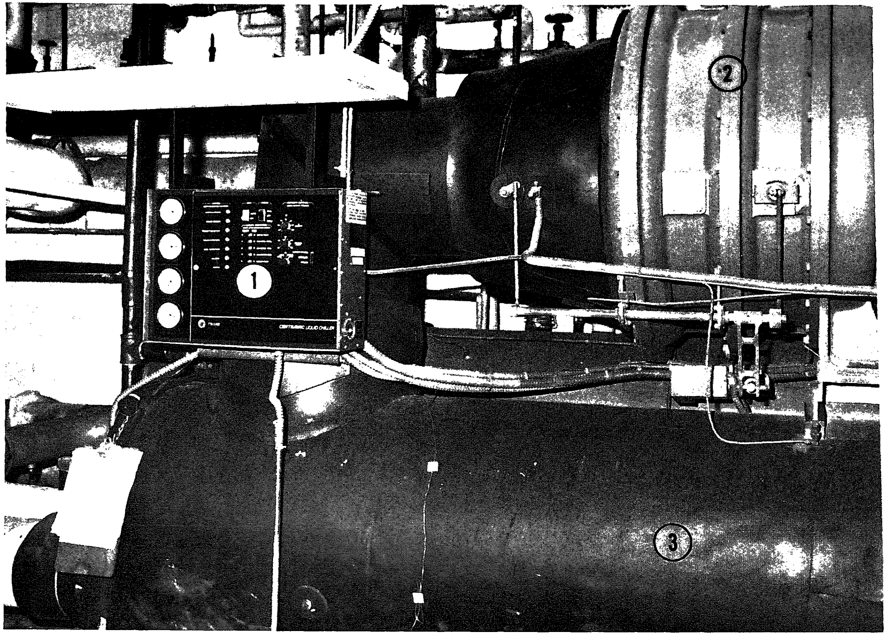
Using too much of a chemical or using the wrong chemical is known as overtreatment. It can materially reduce the performance or the life of a cooling tower condenser circuit.

COMPRESSORS

A compressor is the machine used to withdraw the heat-laden refrigerant vapor from the evaporator, compress it from the evaporator pressure to the condensing pressure, and push it to the condenser. A compressor is merely a simple pump that compresses the refrigerant gas. Compressors may be divided into the following three types: reciprocating, rotary, and centrifugal. The function of compressing a refrigerant is the same in all three general types, but the mechanical means differ considerably. Rotary compressors are used in small sizes only, and their use is limited almost exclusively to domestic refrigerators and small water coolers. Centrifugal compressors are used in large refrigerating and air-conditioning systems. (See figs. 14-12 through 14-15.)

RECIPROCATING COMPRESSORS

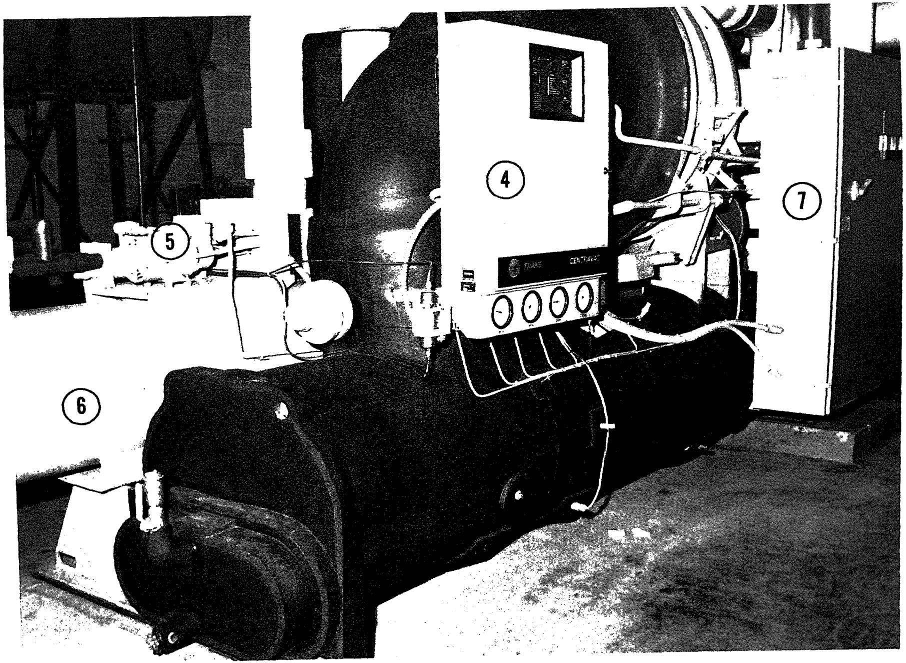
Reciprocating compressors are usually powered by electric motors, although gasoline, diesel, and turbine drivers are sometimes used. In



1. Solid-state control panel.
2. Wheel section.
3. Chiller section.

54.621

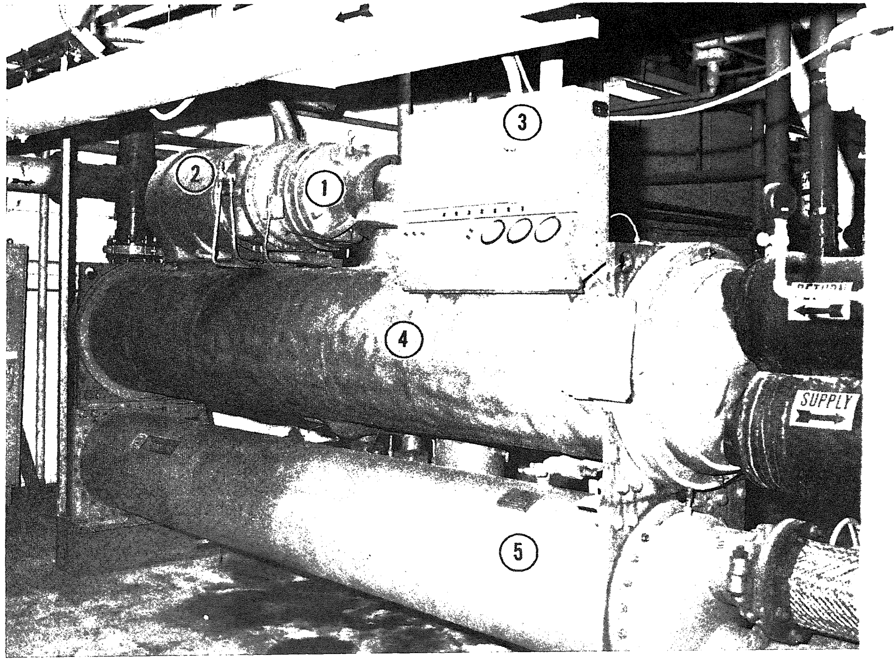
Figure 14-12.—Three-stage semi-hermetic centrifugal compressor, view A.



4. State-of-the-art computerized self-diagnosing control panel.
5. Oilless purge unit.
6. Condenser section.
7. Motor contactor section.

54.622

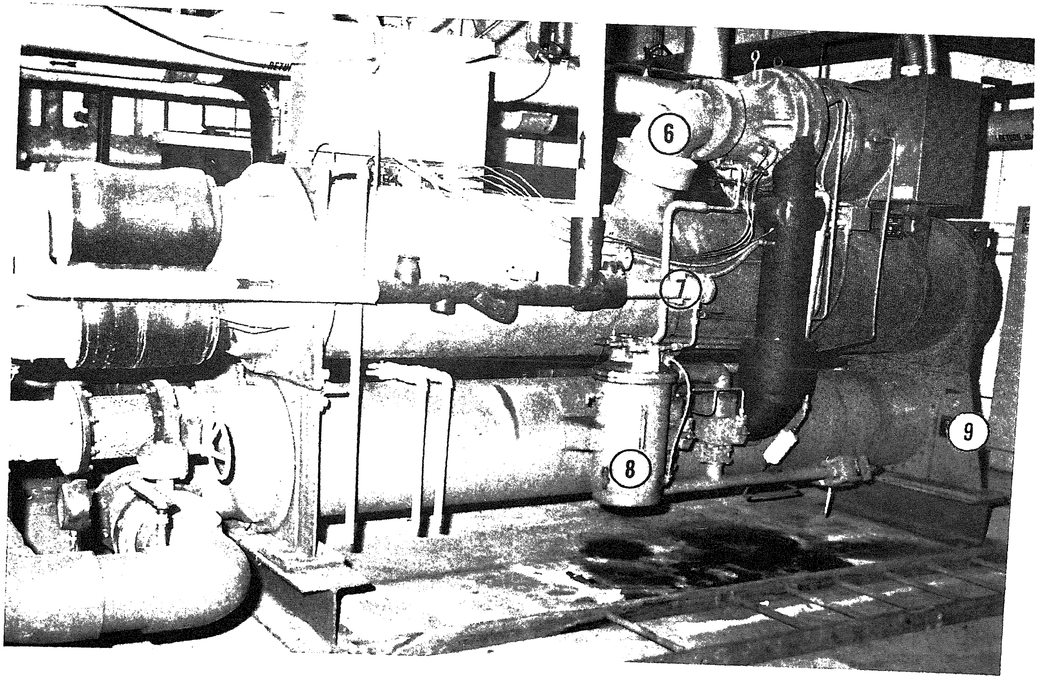
Figure 14-13.—Three-stage semi-hermetic centrifugal compressor, view B.



1. Centrifugal compressor with 5-inch impeller.
2. Refrigerant cooled motor.
3. Control center.
4. Chiller section.
5. Condenser section.

54.623

Figure 14-14.—High-speed (36,000 rpm) single-stage F-12 centrifugal chiller, front view.



6. Suction return.
7. Oil cooler.
8. Oil sump and semi-hermetic oil pump.
9. Hot-gas discharge.

Figure 14-15.—High-speed (36,000 rpm) single-stage F-12 centrifugal chiller, back view. 54.624

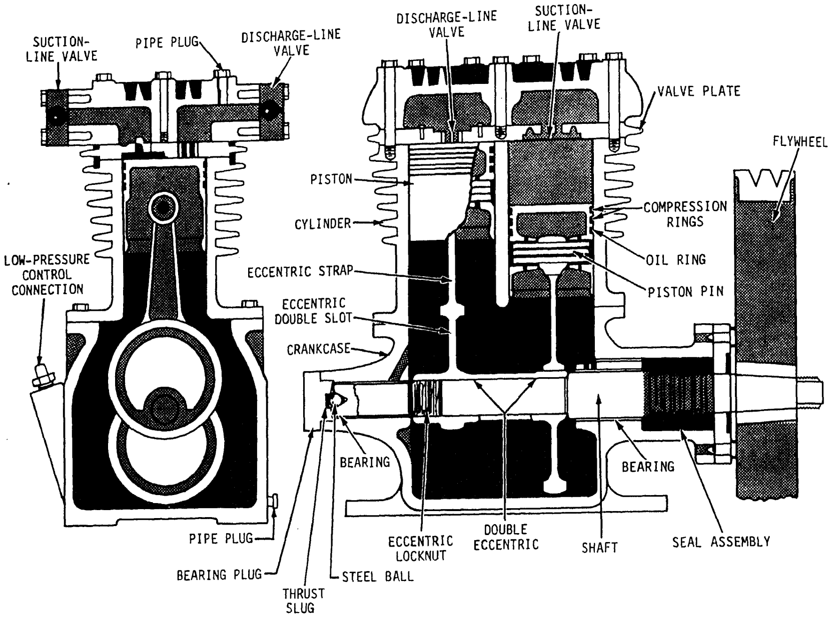


Figure 14-16.—Cross section of an open type of eccentric-shaft compressor.

terms of capacity, reciprocating compressors are made in fractional horsepower for small, self-contained air conditioners and refrigeration equipment, increasing in size to about 250 tons or more capacity in larger installations. Reciprocating compressors are furnished in open, semisealed, and sealed (hermetic) types.

Open

An open type of compressor shaft is driven by an external motor. The shaft passes through the crankcase housing and is equipped with a shaft seal to prevent refrigerant and oil from leaking or moisture and air from entering the compressor. Pistons are actuated by crankshafts or eccentric drive mechanisms mounted on the shaft. Discharge valves are usually mounted in a plate over the pistons. Suction valves are usually mounted either in the pistons, if suction vapors enter the cylinder through the side of the cylinder or through the crankcase, or in the valve plate over the pistons, if suction vapors enter the cylinder through the head and valve plate.

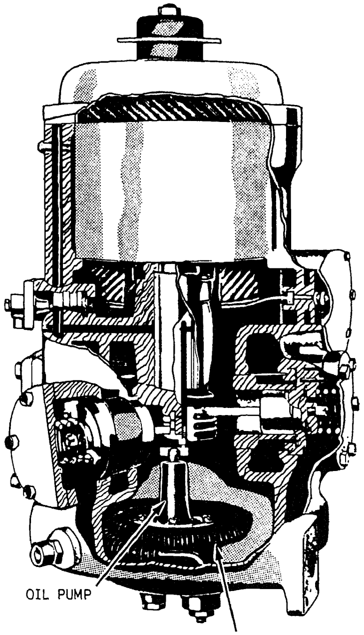
Figure 14-16 shows a cross section of a typical open type of eccentric shaft compressor with suction valves in the valve plate of the head. Most belt-driven open-type compressors under 3 horsepower use a splash feed lubrication, but in larger size compressors, forced feed systems having positive displacement oil pumps are more common. The oil pump is usually driven from the rear end of the main shaft. Oil from the crankcase is forced under pressure through a hole in the main shaft to the seal, main bearing, and rod bearing, and through a hole in the rod up to the piston pins. Hermetically sealed compressor units used in window air conditioners are quite common in commercial sizes (under 5 horsepower) and are even made by some manufacturers in large tonnage sizes.

Semisealed

Semisealed compressors are sometimes made in small sizes, but large tonnage units are always of the semisealed type. The main difference between a fully sealed and a semisealed motor compressor is that in semisealed types the valve plates, and sometimes the oil pump, are accessible and removed for repair or replacement. This type of construction is helpful in larger sizes that are so bulky they would cause considerable trouble and expense in shipping, removing, and replacing the unit as a whole. Figure 14-17 shows a small semisealed compressor.

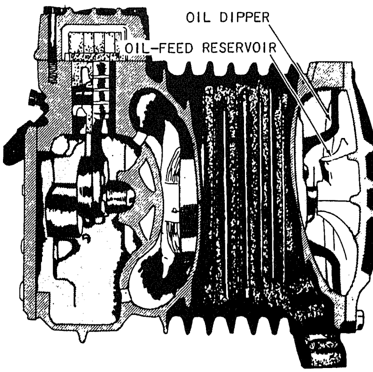
Sealed or semisealed units eliminate the belt drive and crankshaft seal, both of which are among the chief causes of service calls. Sealed and semisealed compressors are made either vertical or horizontal. The vertical type (fig. 14-18) usually has a positive displacement oil pump that forces oil under pressure of 10 to 30 psi to the main bearings, rod, or eccentric and pins, although they are sometimes splash oiled.

Although oil pumps for forced feed lubrication are also used on horizontal hermetic compressors, oil circulation at low oil pressure may be provided by slingers, screw type of devices, and the like. Splash and other types of oil feed must not be considered inferior to forced feed. With good design, they lubricate well. It is most important to maintain the proper oil level, use a correct grade of oil, and keep the system clean and free of dirt and moisture. This is true for all compression refrigeration systems, especially those equipped with hermetically sealed units whose motor windings may be attacked by acids or other corrosive substances, introduced into the system or formed by the chemical reaction of moisture, air, or other foreign substances.



54.573

Figure 14-18.—Vertical semisealed compressor.

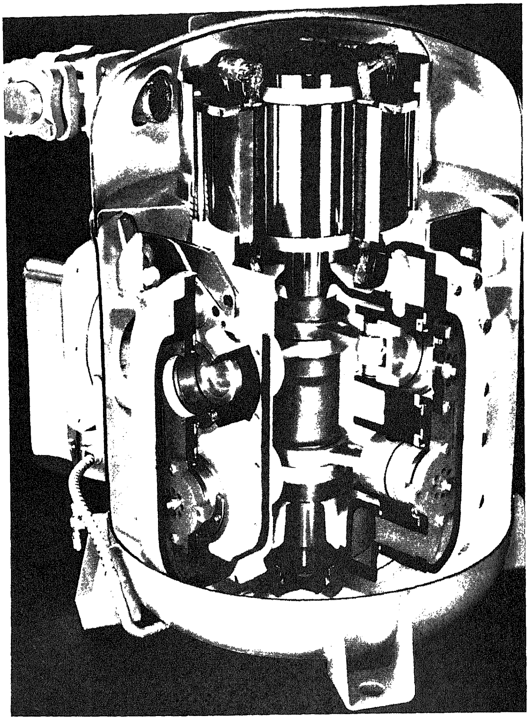


54.572

Figure 14-17.—Small semisealed compressor.

Hermetic

The term *sealed* or *hermetic* unit merely means that the motor rotor and compressor crankshaft of the refrigeration system are made in one piece, and the entire motor and compressor assembly is



Reprinted by permission of the Trane Company.

54.625X

Figure 14-19.—A 1,750 rpm unloading hermetic compressor.

put into a gastight housing that is welded shut (fig. 14-19). This method of assembly eliminates the need for certain parts found in the open unit. These parts are as follows: motor pulley, belt, compressor flywheel, and compressor seal. The elimination of the preceding parts in the sealed unit similarly does away with the following service operations: replacing motor pulleys, replacing flywheels, replacing belts, aligning belts, and repairing or replacing seals. When it is realized there are major and minor operations that maintenance personnel must perform and the sealed unit dispenses with only five of these, it can be readily seen that servicing is still necessary.

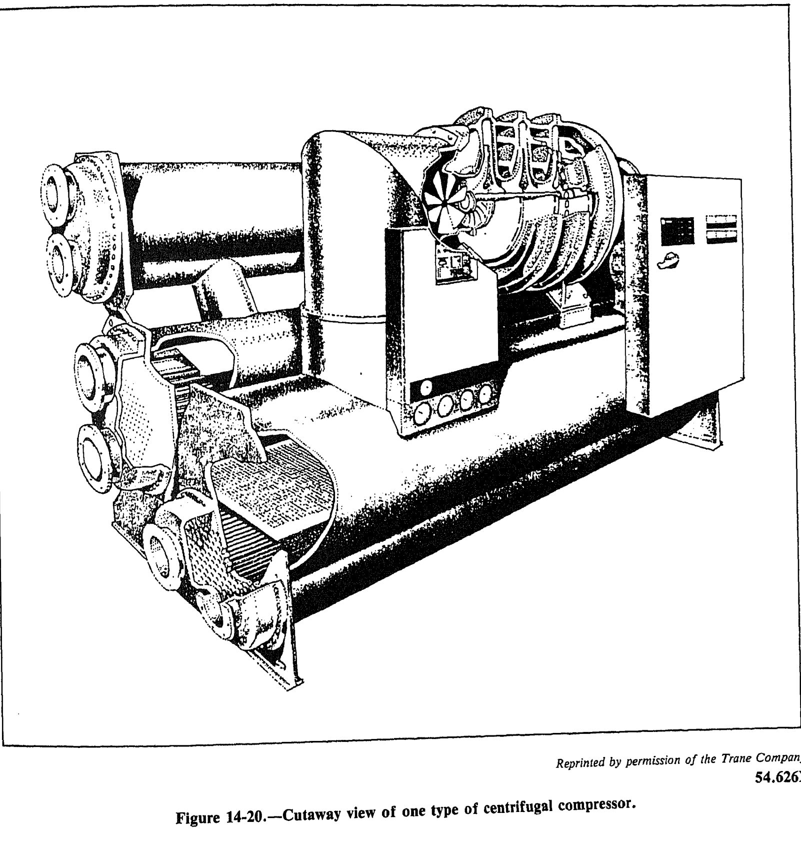
ROTARY COMPRESSORS

Rotary compressors are generally associated with refrigerators, water coolers, and similar small capacity equipment. However, they are available in larger sizes. A typical application of a large compressor is found in compound compressor systems, where high capacity must be provided with a minimum of floor space.

In a rotary compressor, an eccentric rotor revolves within a housing in which the suction and discharge passages are separated by means of a sealing blade. When the rotating eccentric first passes this blade, the suction area is at a minimum. Further rotation enlarges the space and draws in the charge of refrigerant. As the eccentric again passes the blade, the gas charge is shut off at the inlet, compressed, and discharged from the compressor. There are variations of this basic design, some of which provide the rotor with blades to trap and compress the vapor.

CENTRIFUGAL COMPRESSORS

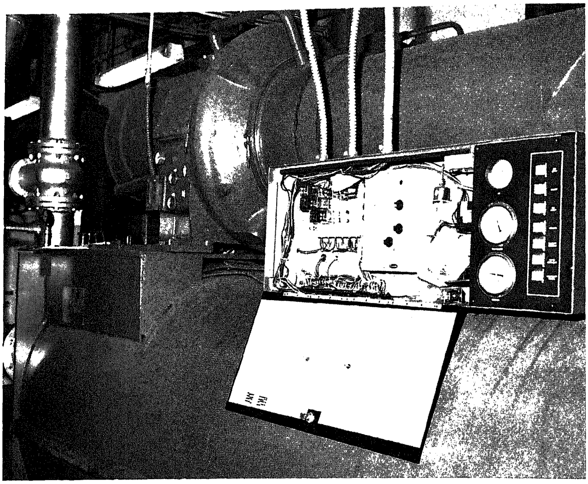
Centrifugal compressors are used in large refrigeration and air-conditioning systems handling large volumes of refrigerants at low-pressure differentials. Their operating principles are based on the use of centrifugal force as a means of compressing and discharging the vaporized refrigerant. Figure 14-20 is a cutaway view of one type of centrifugal compressor. In this application, one or two compression stages are used, and the condenser and evaporator are integral parts of the unit. The heart



Reprinted by permission of the Trane Company.

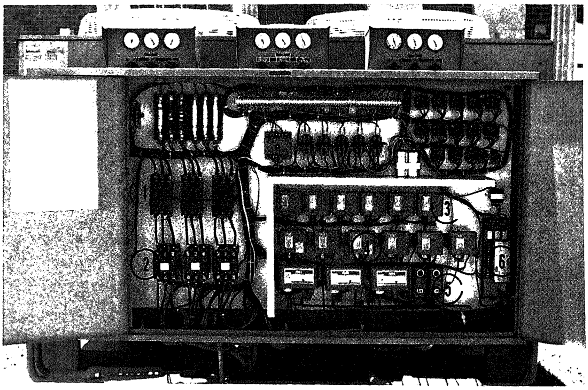
54.626X

Figure 14-20.—Cutaway view of one type of centrifugal compressor.



54.627

Figure 14-21.—Single-stage semi-hermetic centrifugal chiller with solid-state control package.



1. Compressor breakers.
2. Compressor starters.
3. Fan cycle controls.
4. High-pressure controls.
5. Oil failure controls.
6. Solid-state staging thermostat.

54.628

Figure 14-22.—Packaged air-cooled chiller controls.

of this type of compressor is the impeller wheel.

CONTROLS

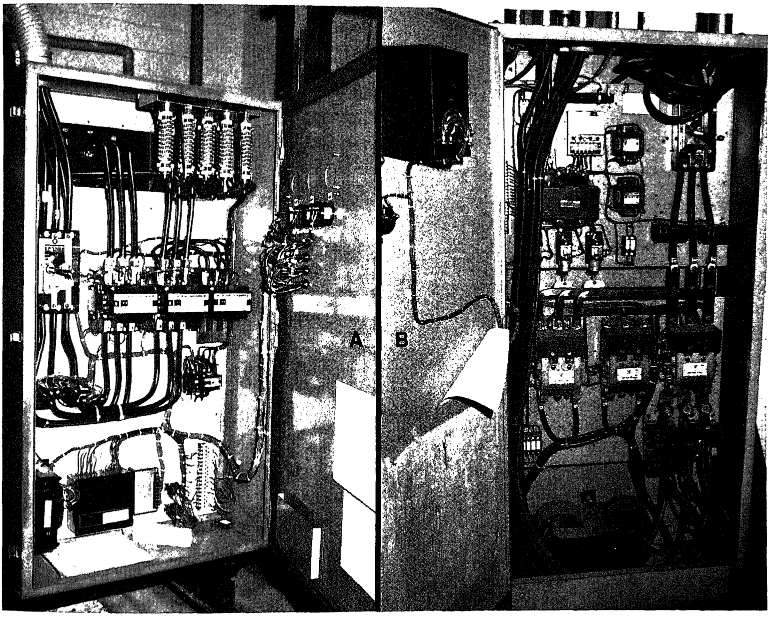
Controls used in air-conditioning are generally the same as for refrigeration systems—thermostats, humidistats, pressure and flow controllers, and motor overload protectors. (See figs. 14-21 through 14-23.)

THERMOSTATS

The thermostat is an adjustable temperature-sensitive device which, through the opening and closing of its contacts, controls the operation of the cooling unit. The temperature-sensitive element may be a bimetallic strip or a confined, vaporized liquid.

The thermostats used with refrigerative air conditioners are similar to those used with heating equipment, except their action is reversed. The operating circuit is closed when the room temperature rises to the thermostat control point and remains closed until the cooling unit decreases the temperature enough. Also, cooling thermostats are not equipped with heat-anticipating coils.

Wall type of thermostats most common for heating and air conditioning in the home and on some commercial units use a bimetallic strip and



54.629

Figure 14-23.—Centrifugal motor control centers. Both systems do the same thing. A. State-of-the-art motor control with solid-state components. B. Conventional motor control with current transformers, dash pots, mechanical interlocks, and auto transformers.

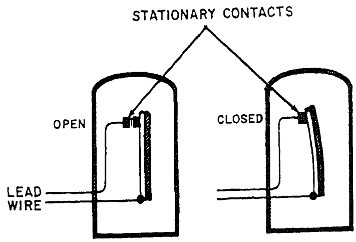


Figure 14-24.—Bimetallic thermostat.

a set of contacts, as shown in figure 14-24. This type of thermostat operates on the principle that when two dissimilar metals, such as brass and steel, are bonded together, one tends to expand faster than the other when heat is applied. This causes the strip to bend and close the controls.

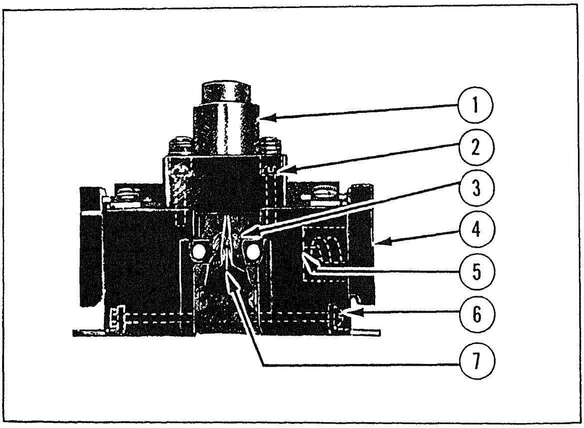
As a Utilitiesman, you may be required to make an adjustment that sets the temperature difference between the cut-in and cut-out temperatures. For example, if the system is set to cut in at 76 °F and cut out at 84 °F, then the differential is 8 °F. This prevents the unit from cycling continually as it would if there were no differential.

HUMIDISTATS

A room "humidistat" may be defined as a humidity-sensitive device controlling the equipment that maintains a predetermined humidity of the space where it is installed. The contact of the humidistat is opened and closed by the expansion or contraction of natural blonde hairs from human beings, which is one of the major elements of this control. It has been found that these types of hairs are most sensitive to the moisture content of the air surrounding them.

PRESSURE-FLOW CONTROLLERS

Pressure-flow controllers are discussed in the *Utilitiesman 3*, NAVEDTRA 10663, chapter 10. The purpose of these controllers in air conditioning is to act as safety switches for the system, so if either the head pressure is too high or suction pressure too low, the system will be secured



1. Contact structure.
2. Screw.
3. Operating arm.
4. Heater coil.
5. Solder tube.
6. Screw.
7. Splitter arm.

77.101

Figure 14-25.—Thermal overload relay.

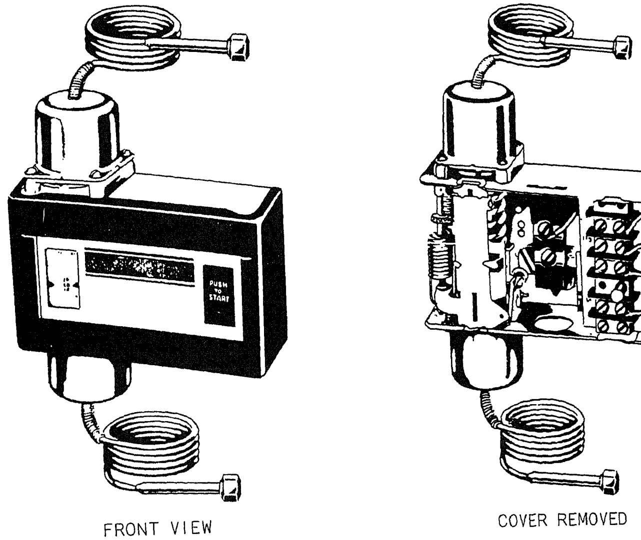


Figure 14-26.—Oil failure cutout switch.

regardless of the position of the operating switches.

REFRIGERANT-FLOW CONTROLLERS

The refrigerant-flow controllers used with air conditioners are also similar to the ones discussed in the *Utilitiesman 3*. These controllers are either of the capillary type or externally equalized expansion valve type and are usually of larger tonnage than those used for refrigerators.

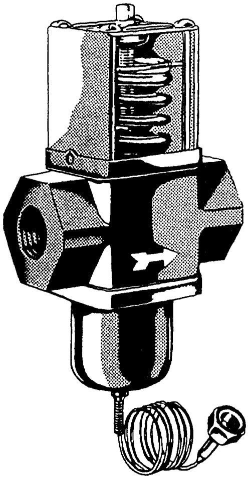
MOTOR OVERLOAD PROTECTORS

When the compressor is powered by an electric motor, either belt driven or as an integral part of the compressor assembly, the motor is usually protected by a heat-actuated overload device. This is in addition to the line power fuses. The heat to actuate the overload device is supplied by the electrical energy to the motor, as well as the heat generated by the motor itself. Either source of heat or a combination of the two, if too much, causes the overload device to open and remove the motor from the line.

Figure 14-25 shows a thermal-element type of overload cutout relay. It is housed in the magnetic starter box. On current overload, the relay contacts open, allowing the holding coil to release the starting mechanism, thereby stopping the motor.

An oil failure cutout switch is provided on many systems to protect the compressor against oil failure. The switch is connected to register pressure differential between the oil pump and the suction line. Figure 14-26 shows a typical oil failure cutout switch. The switch contains two bellows, which work against each other, and springs for adjusting. Tubing from the oil pump is connected to the bottom bellows of the switch. Tubing from the suction line is connected to the upper bellows. When a predetermined pressure differential is not maintained, a pair of contacts in the switch is opened and breaks the circuit to the compressor motor. A heating element with a built-in delay is in the switch to provide for starting the compressor when oil pressure is low.

The water-regulating valve used with a water-cooled condenser responds to a predetermined condensing pressure. A connection from the discharge side of the compressor to the valve transmits condensing pressure directly to a



54.578

Figure 14-27.—Water-regulating valve.

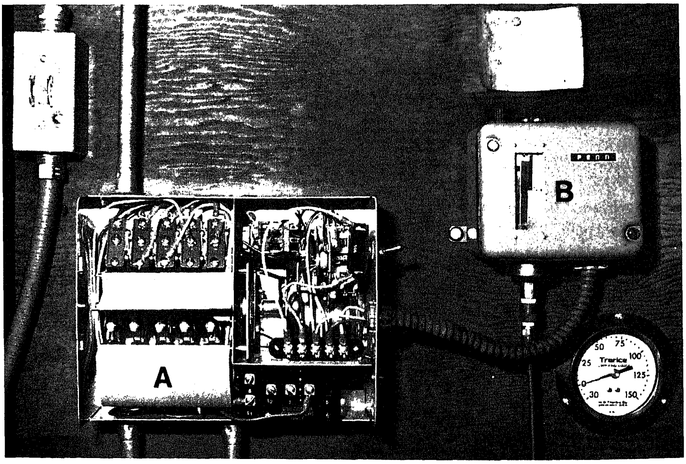
bellows inside the valve. High pressure opens the valve, allowing a greater flow of water; low pressure throttles the flow. Use of such a valve provides for a more economical use of water for condensing. Figure 14-27 shows a typical water-regulating valve. When condenser water is supplied by a cooling tower, water-regulating valves are not customarily used because the cooling tower fan and circulating pump are wired into the compressor motor control circuit.

STEP CONTROLLER

The step controller contains a shaft upon which is mounted a series of cams. Rotation of the cams, in turn, operates electrical switches. Through adjustment of the cams on the shaft, the temperature at which each switch is to close and open (differential) is established. In addition, the switches may be adjusted to operate in almost any sequence. (See fig. 14-28.)

TROUBLESHOOTING

Table 14-1 is a troubleshooting chart generally applicable to all types of air conditioners. Most manufacturers include more detailed



54.630

Figure 14-28.—Step controller and pressure-sensor configuration. A. Step controller with modulating motor, single-pole double-throw mini switches, and mouse trap relay assembly. B. Pressure sensor that controls the step controller.

Table 14-1.—Troubleshooting Chart for Air-Conditioners

Type of Unit	Complaint	Cause	Possible remedy
With open-type compressor	Electric motor will not start	Power failure	Check circuit for power source
		Compressor stuck	Locate cause and repair
		Belt too tight	Adjust belt tension
		Manual reset in starter open	Determine cause of overload and repair. Reset overload cutout
		Thermostat setting too high	Lower thermostat setting
		Low voltage	Check with voltmeter, then call power company
		Burned-out motor	Repair or replace
		Frozen compressor caused by locked or damaged mechanism	Remove and repair compressor
	Unit cycles on and off	Intermittent power interruption	Tighten connections or replace defective power supply parts
		High-pressure cutout defective	Replace high-pressure cutout
		High-pressure cutout set too low. Overload opens after having been reset	Raise cutout pressure. Check voltage and current drawn
		Leaky liquid-line solenoid valve	Repair or replace
		Dirty or iced evaporator	Clean or defrost evaporator. Check filters and fan drive
		Overcharge of refrigerant or non-condensible gas	Remove excess refrigerant or purge noncondensible gas
		Lack of refrigerant	Repair refrigerant leak and re-charge
		Restricted liquid-line strainer	Clean strainer
		Faulty motor	Repair or replace faulty motor
	Coil frosts	Filters dirty	Clean filters
		Not enough air over coil	Clean or remove restriction from supply or return ducts or grilles
		Defective expansion valve	Replace valve
	Unit runs but will not cool	Unit not fully charged	Recharge slightly, then check for leaks in the refrigerant circuit, then fully charge
		Leaky suction valve or discharge valve	Remove compressor cylinder head and clean or replace valve plate
		Expansion valve not set correctly	Adjust expansion valve
		Strainer clogged	Remove, clean, and replace strainer
		Air in refrigerant circuit. Moisture in expansion-valve orifice	Purge unit of air. Clean orifice and install silica gel dryer
		Flash gas in liquid line	Add refrigerant

Table 14-1.—Troubleshooting Chart for Air-Conditioners—Continued

Type of Unit	Complaint	Cause	Possible remedy
With open-type compressor—Continued	No air blows from supply grille	Ice or dirt on evaporator	Clean coil or defrost
		Blower belt broken or loose	Adjust belt tension, or replace belt
		Blower bearing frozen	Repair or replace bearing and lubricate as directed
	Discharge pressure too high	Improper operation of condenser	Correct airflow. Clean coil surface
		Air in system	Purge
		Overcharge of refrigerant	Remove excess or purge
	Discharge pressure too low	Lack of refrigerant	Repair leak and charge
		Broken or leaky compressor discharge valves	Remove head, examine valves and replace those found to be operating improperly
	Suction pressure too high	Overfeeding of expansion valve	Regulate superheat setting expansion valve and check to see that remote bulb is properly attached to suction line
		Expansion valve stuck in open position	Repair or replace valve
		Broken suction valves in compressor	Remove head, examine valves and replace those found to be inoperative
	Suction pressure too low	Lack of refrigerant	Repair leak and charge
		Clogged liquid line strainer	Clean strainer
		Expansion-valve power assembly has lost charge	Replace expansion-valve power assembly
		Obstructed expansion valve	Clean valve and replace if necessary
		Contacts on control thermostat stuck on closed position	Repair thermostat or replace if necessary
With hermetic motor-compressor combination	Compressor runs continuously; good refrigeration effect	Air over condenser restricted	Remove restriction or provide for more air circulation over the condenser
	Compressor runs continuously; unit is too cold	Thermostatic switch contacts badly burned	Replace thermostatic switch
		Thermostatic switch bulb has become loose	Secure bulb in place
		Thermostatic switch improperly adjusted	Readjust thermostatic switch
	Compressor runs continuously; little refrigeration effect	Extremely dirty condenser	Clean condenser
		No air circulating over condenser	Provide air circulation
		Ambient temperature too high	Provide ventilation or move to a cooler location
		Load too great	Analyze load

Table 14-1.—Troubleshooting Chart for Air-Conditioners—Continued

Type of Unit	Complaint	Cause	Possible remedy
With hermetic motor-compressor combination—Continued	Compressor runs continuously; no refrigeration	A restriction that prevents the refrigerant from entering the evaporator. A restriction is usually indicated by a slight refrigeration effect at the point of restriction	Locate the possible points of restriction, and try jarring with a plastic hammer, or heating to a temperature of about 110 degrees F. If the restriction does not open, replace the unit
		Compressor not pumping. This would be indicated by a cool discharge line and a hot compressor housing. The wattage is generally low	Replace the unit
		Short of refrigerant	See manufacturer's instructions
	Compressor short cycles, poor refrigeration effect	Loose electrical connections	Locate loose connections and make them secure
		Defective thermostatic switch	Replace thermostatic switch
		Defective motor starter	Replace defective motor starter or relay
		Air restriction at evaporator	Remove air restriction
	Compressor short cycles, no refrigeration	Dirty condenser	Clean the condenser
		Ambient temperature too high	Provide ventilation or move to a cooler location
		Defective wiring	Repair or replace defective wiring
		Thermostatic switch operating erratically	Replace thermostatic switch
		Relay erratic	Replace relay
	Compressor runs too frequently	Poor air circulation around the condenser or too high ambient temperature	Increase the air circulation around the condenser. In some localities the temperature is extremely high, and nothing can be done to correct this
		Load too great. Worn compressor. Generally accompanied by rattles and knocks	Analyze end use. Replace unit or bring it to the shop for repairs
	Compressor does not run	Motor is not operating	If the trouble is outside the sealed unit, it should be corrected; for example, wires should be repaired or replaced and thermostatic switches or relays should be replaced. If the trouble is inside the sealed unit, the sealed unit should be replaced
	Compressor will not run (Assume that the thermostatic switch and relay, and the electric wiring and current supply are in good condition and operating normally)	If the cabinet has been moved, some oil may be on top of the piston	Wait an hour or so, and then attempt to start the motor by turning the current on and off many times. On some compressors, it may be necessary to wait 6 or 8 hours

Table 14-1.—Troubleshooting Chart for Air-Conditioners—Continued

Type of Unit	Complaint	Cause	Possible remedy
With hermetic motor-compressor combination—Continued	Compressor will not run (Assume that the thermostatic switch and relay, and the electric wiring and current supply are in good condition and operating normally)—Continued	Compressor may be stuck, or some parts may be broken	Replace the unit
		Connections may be broken on the inside of the unit, or the motor winding may be open	Replace the unit. Sometimes after sealed units have been standing idle for a long time, the piston may stick in the cylinder wall. It is sometimes possible to start the compressor by turning on the current and bumping the outer housing with a rubber mallet.
	Compressor is unusually hot	Condenser is dirty, or there is a lack of air circulation	Clean the condenser; increase the air circulation
		Unusually heavy service or load	If possible, decrease load. Perhaps another unit is required
		Low voltage	This could be caused by too small feed wires. If the wires feeding the refrigerating unit become warm, it is an indication that they are too small and should be replaced with larger wires
		A shortage of oil	Add oil if possible; if this is not possible, the unit must be replaced. A shortage of refrigerant will cause a shortage of oil in the crankcase of the compressor
	No refrigeration after starting up after a long shutdown or on delivery	Generally, during a long shutdown, an amount of liquid refrigerant will get into the crankcase of the compressor. When this happens, the compressor operation will cause no noticeable refrigeration effect until all the liquid refrigerant has evaporated from the crankcase	Allow the compressor to operate until its internal heat drives the liquid refrigerant from the crankcase. Under some conditions, this may take as long as 24 hours. This time can be shortened by turning an electric heater on the compressor and raising the compressor temperature, not exceeding 110 degrees F.
	Compressor is noisy	Mountings have become worn or deteriorated. The walls against which the unit is placed may be of an extremely hard surface and may resound and amplify the slight noise from the compressor into the room	Replace the rubber mountings. Place a piece of sound-absorbing material on the wall against which the unit is placed, or move the unit to a new location
		Shortage of oil and/or refrigerant	Add oil and refrigerant if possible. If it is impossible, the unit must be replaced
		The sealed unit mechanism has become worn	Replace the unit

Table 14-1.—Troubleshooting Chart for Air-Conditioners—Continued

Type of Unit	Complaint	Cause	Possible remedy
With hermetic motor-compressor combination—Continued	After each defrosting there is a long on cycle before refrigeration is again normal	Slight shortage of refrigerant	Add refrigerant if possible; if not, replace the unit
		Condenser is dirty	Clean the condenser
		Thermostatic switch bulb is loose	Secure the bulb in place
		There is a restriction between the receiver or condenser and/or the evaporator	Attempt to remove the restriction by jarring with a plastic hammer or by heating the possible points of restriction to about 110 degrees F. If this does not correct the trouble, the unit must be replaced or brought to the shop for repairs

and specific information (table 14-2) in publications pertaining to their units. If you find that there is no manual with the unit when it is unpacked, write to the manufacturer and request one as soon as possible.

AUTOMOTIVE AIR CONDITIONING

Vehicle air conditioning is the cooling (refrigeration) of air within a passenger compartment. Refrigeration is accomplished by making practical use of three laws of nature. These laws of nature and their practical application are outlined below.

HEAT TRANSFER

If two substances of different temperature are placed near each other, the heat in the warmer substance always travels to the colder substance until both are of equal temperature. For example, a cake of ice in an ice box does not communicate its coldness to the bottle of milk

Table 14-2.—Troubleshooting Chart

SYMPTOM	PROBABLE CAUSE	RECOMMENDED ACTION
A. Compressor does not start, and does not hum.	1. No power to unit.	1. Check for the following: a. Disconnect switch open. b. Fuses blown.
	2. No call for cooling.	2. Check for the following: a. Defective thermostat. b. Broken or improper control wiring. c. Blown control power fuse.
	3. Anti-recycle timer has not timed out (if installed).	3. Wait at least 5 minutes for the anti-recycle timer to time out.
	4. Unit locked out by reset relay.	4. Check for the following: a. Excessive discharge pressure. Refer to Symptom L, "Discharge pressure too high." b. Defective high-pressure control. c. Compressor winding stat open. Refer to Low Suction Pressure. d. Defective comp. protector or fuse-check for winding stats shorted to motor windings. e. Defective reset relay contact. f. Comp. current overload open. Refer to Symptom F.

54.X

Table 14-2.—Troubleshooting Chart—Continued

SYMPTOM	PROBABLE CAUSE	RECOMMENDED ACTION
A. Compressor does not start, and does not hum—Continued.	5. Compressor contactor will not close.	5. Check for the following: a. Defective comp. contactor. b. Improper wiring. c. Reset relay open. d. Low-pressure control open. e. Cooling relay not energized. Defective relay-check thermostat circuit. See Symptom A, Cause 2.
	6. Compressor winding stat open.	6. Refer to Symptom F. a. Check compressor amp draw. b. Defective low-pressure control - replace.
B. Compressor hums, but will not start.	1. Low voltage at the compressor.	1. Check for the following: a. A single blown fuse. b. Low line voltage. c. Defective compressor contactor. d. Loose wiring connections. e. Defective part winding start time delay.
	2. Defective compressor.	2. Check for the following: a. Open motor winding. b. Excessive amp draw on all phases.
C. Second-stage compressor fails to start.	1. Time delay contacts fail to close.	1. Replace time delay relay.
	2. No call for cooling.	2. Check for the following: a. Defective thermostat. b. Broken or improper control wiring.
	3. Unit locked out by reset relay.	3. Same as A-4.
	4. Compressor contactor will not close.	4. Same as A-5.
D. Compressor short cycles.	1. Intermittent contact in control circuit.	1. Check for the following: a. Defective relay contacts. b. Loose wiring connections.
	2. Poor thermostat placement.	2. Refer to "Thermostat Installation" in the ELECTRICAL WIRING section of this manual.
	3. Defective anti-recycle timer.	3. Replace.
	4. Defective liquid line solenoid valve.	4. Replace.
	5. Low refrigerant charge.	5. Check for leak, add refrigerant.
	6. Plugged liquid line filter-driers.	6. Replace.
	7. Defective low pressure control.	7. Replace.
	8. Defective low ambient time delay relay.	8. Replace.

Reprinted by permission of the Trane Company.

54.X

Table 14-2.—Troubleshooting Chart—Continued

SYMPTOM	PROBABLE CAUSE	RECOMMENDED ACTION
E. Compressor runs continuously.	1. Unit undersized for load (cannot maintain space temperature).	1. Check for cause of excessive load.
	2. Thermostat set point too low.	2. Readjust thermostat.
	3. Defective thermostat or control wiring (conditioned space too cold).	3. Replace thermostat. Replace or repair control wiring.
	4. Welded contacts on compressor contactor.	4. Repair or replace contactor.
	5. Leaky valves in compressor (indicated by operation at abnormally low discharge and high suction pressures).	5. Replace compressor.
	6. Shortage of refrigerant (indicated by reduced capacity coupled with high superheat, low subcooling, and low suction pressure).	6. Find and repair refrigerant leak. Recharge system.
	7. Liquid line solenoid valve stuck open.	7. Repair/replace.
	8. Defective low pressure control.	8. Replace.
F. Compressor motor winding stat open.	1. Excessive load on evaporator (indicated by high supply air temperature).	1. Check for the following: a. Excessive airflow. b. High return air temperature.
	2. Lack of motor cooling (indicated by excessive superheat).	2. Check for the following: a. Improper expansion valve setting. b. Faulty expansion valve. c. Restriction in liquid line.
	3. Improper voltage at compressor.	3. Check for the following: a. Low or imbalanced line voltage. b. Loose power wiring. c. Defective compressor contactor.
	4. Internal parts of compressor damaged.	4. Replace compressor.
G. Compressor is noisy.	1. Internal parts of compressor damaged or broken (compressor knocks).	1. Replace compressor.
	2. Liquid flood back (indicated by abnormally cold suction line and low superheat).	2. Check and adjust superheat.
	3. Liquid refrigerant in the compressor at start-up. (Indicated by abnormally cold compressor shell).	3. Replace crankcase heater.

Reprinted by permission of the Trane Company.

54.X

Table 14-2.—Troubleshooting Chart—Continued

SYMPTOM	PROBABLE CAUSE	RECOMMENDED ACTION
H. System short of capacity.	1. Low refrigerant charge (indicated by low subcooling and high superheat).	1. Add refrigerant.
	2. Clogged filter drier (indicated by temperature change in refrigerant line through drier).	2. Replace filter drier or core of drier.
	3. Incorrect thermostatic expansion valve setting.	3. Readjust expansion valve.
	4. Expansion valve stuck or obstructed (indicated by high superheat and high space temperature).	4. Repair or replace expansion valve.
	5. Low evaporator airflow.	5. Check filters. Adjust airflow.
	6. Noncondensibles in system.	6. Evacuate and recharge system.
	7. Leaky valves in compressor (indicated by operation at abnormally low discharge and high suction pressures).	7. Replace compressor.
I. Suction presssure too low.	1. Shortage of refrigerant (indicated by high superheat and low subcooling).	1. Find and repair refrigerant leak. Recharge system.
	2. Thermostat set too low (indicated by low discharge pressure and low space temperature).	2. Readjust thermostat.
	3. Low airflow.	3. Check for clogged filters, incorrect fan speed, or high duct static pressure.
	4. Clogged filter drier.	4. Check for frosting on filter drier. Replace if necessary.
	5. Expansion valve power assembly has lost charge.	5. Repair or replace expansion valve power head assembly.
	6. Obstructed expansion valve (indicated by high superheat).	6. Clean or replace valve.
J. Suction pressure too high.	1. Excessive cooling load (indicated by high supply air temperatures).	1. See Symptom E. "Compressor runs continuously."
	2. Overfeeding of expansion valve (indicated by abnormally low superheat and liquid flooding to compressor).	2. Adjust superheat setting and check to see that remote bulb is properly attached to suction line.
	3. Suction valves broken (indicated by noisy compressor.	3. Replace compressor.

Reprinted by permission of the Trane Company.

54.X

Table 14-2.—Troubleshooting Chart—Continued

SYMPTOM	PROBABLE CAUSE	RECOMMENDED ACTION
K. Discharge pressure too low.	1. Shortage of refrigerant (indicated by low subcooling and high superheat plus bubbles in sight glass).	1. Repair leak and recharge system.
	2. Broken or leaky compressor discharge valves (indicated by suction and discharge pressures that equalize rapidly after shutdown).	2. Replace compressor.
	3. Condenser fan control stuck in closed position (contacts closed when pressure is below 155 psig).	3. Replace defective control.
	4. Unit running below minimum operating ambient.	4. Provide adequate heat pressure controls or a unit ambient lockout switch.
	5. Low ambient damper stuck open (indicated by low discharge pressure).	5. Repair or replace damper operator.
L. Discharge pressure too high.	1. Too little or too warm condenser air; restricted airflow.	1. Clean coil. Check fan and motors for proper operation.
	2. Air or noncondensible gas in system (indicated by exceptionally hot condenser and excessive discharge pressure).	2. Evacuate and recharge system.
	3. Overcharge of refrigerant (indicated by high subcooling, low superheat, and high suction pressure).	3. Remove excess refrigerant.
	4. Excessive system load.	4. Reduce load.
	5. Defective condenser fan or fan pressure control (indicated by one fan off and high condenser pressure).	5. Repair or replace switch.
	5. Defective or inoperative low ambient dampers.	6. Repair or replace defective parts.

Reprinted by permission of the Trane Company.

54.X

standing nearby. Rather, in obedience to the law of nature, the heat in the warm milk automatically flows into the ice which has a lesser degree of heat. To determine the amount of heat that transfers from one substance to another, science has established a definite standard of measurement called the British thermal unit or Btu. One Btu is the amount of heat required to raise the temperature of 1 pound of water 1 °F. For example, to raise the temperature of 1 pound of water from 32 °F to 212 °F, one Btu of heat must be added for each 1 °F rise in temperature or a total of 180 Btu of heat. Conversely, to lower the temperature of 1 pound of water from 212 °F to 32 °F, 180 Btu of heat must be removed from the water.

LATENT HEAT OF VAPORIZATION

When a liquid boils (changes to a gas), it absorbs heat without raising the temperature of

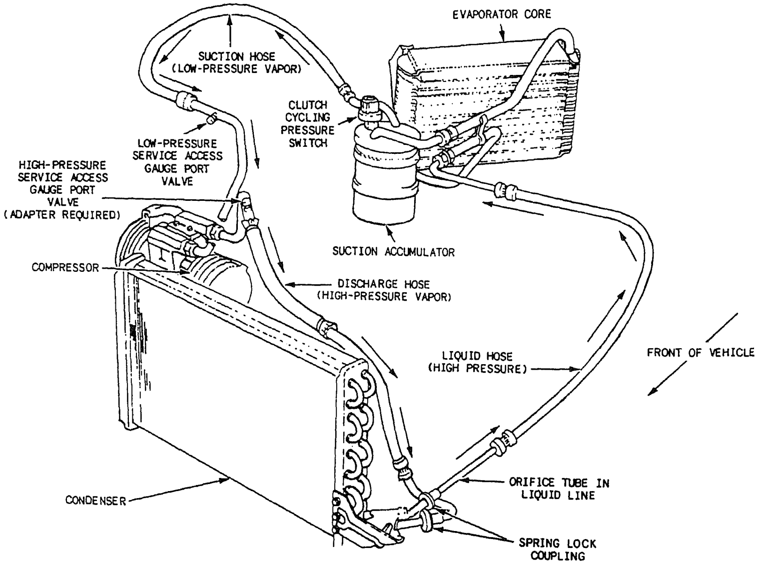
the resulting gas. When the gas condenses (changes back to a liquid), it gives off heat without lowering the temperature of the resulting liquid.

For example, place 1 pound of water at 32 °F in a container over a flame. With each Btu of heat the water absorbs from the flame, its temperature rises 1 °F. Thus, after it has absorbed 180 Btu of heat, the water reaches a temperature of 212 °F. Here the law of nature is encountered. Even though the flame continues to give its heat to the water, the temperature of the water remains at 212 °F. The water, however, starts to boil or change from a liquid to the gaseous state, and it continues to boil until the water has passed off into the atmosphere as vapor. If this vapor were collected in a container and checked with a thermometer, it also would show a temperature of 212 °F. In other words, there was a rise of only 180 °F from 32 °F to 212 °F in the water and vapor temperature, even though the flame applied many more than 180 Btu of heat. In this case, the heat is absorbed by the liquid in the process of boiling and disappears in the vapor. If the vapor were brought in contact with cool air, the hidden heat would reappear and flow into the cooler air as the vapor condensed back to water. Scientists refer to this natural law as the latent (hidden) heat of vaporization.

Water has a latent heat of vaporization of 970 Btu and a boiling point of 212 °F. This means that 1 pound of water at 212 °F absorbs 970 Btu of heat in changing to vapor at 212 °F. Conversely, the vapor gives off 970 Btu of heat in condensing back to water.

This tremendous heat transfer that occurs when a liquid boils or a vapor condenses forms the basic principle of all conventional refrigeration systems.

For a liquid to be a good refrigerant, the amount of heat it absorbs when vaporizing is not the only factor. It must also have a low boiling point; that is, the temperature at which it boils must be lower than the substance to be cooled. To illustrate with water, place a bottle of milk at room temperature of 70 °F next to boiling water at 212 °F. The heat would flow from the (higher temperature) water to the (lower temperature) milk. The milk would be heated rather than



Reprinted with Ford Motor Company's permission by Wendell C. White

54.627X

Figure 14-29.—Air-conditioning refrigeration system—fixed orifice.

cooled, because the boiling point of water is too high.

To make practical use of the heat transfer that takes place when a liquid boils, we must choose a liquid with a low boiling point. Refrigerant 12 is the liquid most commonly used in automotive air-conditioning systems because it boils at 21.7 °F below zero in an open container. Here is a liquid that boils or vaporizes well below the desired passenger compartment temperatures and, in vaporizing, absorbs tremendous amounts of heat without getting any warmer itself.

EFFECT OF PRESSURE ON BOILING OR CONDENSATION

The saturation temperature (the temperature where boiling or condensation occurs) of a liquid or vapor increases or decreases according to the pressure exerted on it.

In the fixed-orifice tube refrigerant system, liquid refrigerant (R-12) is stored in the condenser under high pressure (fig. 14-29). When the liquid (R-12) is released into the evaporator by the fixed orifice tube, the resulting decrease in pressure and partial boiling lowers its temperature to its new boiling point. As the R-12 flows through the evaporator, passenger compartment air passes over the outside surface of the evaporator coils. As it boils, the R-12 absorbs heat from the air and thus cools the passenger compartment. The heat from the passenger compartment is absorbed by the boiling refrigerant and hidden in the vapor. The refrigeration cycle is now under way. The following functions must be done to complete the refrigeration cycle:

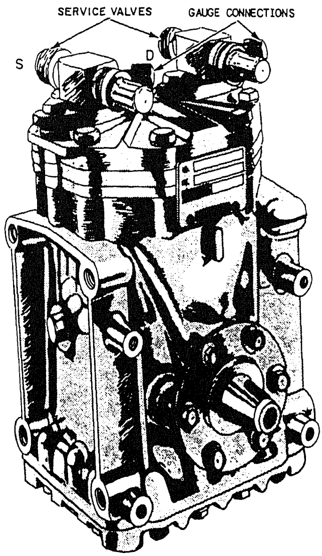
1. Disposing of the heat in the vapor.
2. Converting the vapor back to liquid for reuse.
3. Returning of the liquid to the starting point in the refrigeration cycle.

The compressor and condenser (fig. 14-29) perform these functions. The compressor pumps the refrigerant vapor (containing the hidden heat) out of the evaporator and suction accumulator drier, then forces it under high pressure into the condenser which is located in the outside airstream at the front of the vehicle. The increased pressure in the condenser raises the R-12 condensation or saturation temperature to a point higher than that of the outside air. As the heat transfers from the hot vapor to the cooler air, the R-12 condenses back to a liquid. The liquid under high pressure now returns through the liquid line to the fixed orifice tube for reuse.

It may seem difficult to understand how heat can be transferred from a comparatively cooler vehicle passenger compartment to the hot outside air. The answer lies in the difference between the refrigerant pressure that exists in the evaporator and the pressure that exists in the condenser. In the evaporator, the compressor suction reduces the pressure and the boiling point below the temperature of the passenger compartment. Thus, heat transfers from the passenger compartment to the boiling refrigerant. In the condenser, the compressor raises the condensation point above the temperature of the outside air. Thus, the heat transfers from the condensing refrigerant to the outside air. The fixed orifice tube and the compressor simply create pressure conditions that permit the laws of nature to function.

AUTOMOTIVE COMPRESSORS

Several types of air-conditioning compressors are in use in automotive applications. Belt-driven, reciprocating piston types of compressors are found on many engines. (See fig. 14-30.) Not all



54.575

Figure 14-30.—Automotive air-conditioner compressor.

automotive compressors have crankshafts. The factory at General Motors (GM) installs a Frigidaire six-cylinder, axial piston unit.

The six-cylinder GM compressor has, in effect, three cylinders at each end of its inner assembly. A swash plate of diagonal design is mounted on the compressor shaft. It actuates the pistons, forcing them to move back and forth in the cylinders as the shaft is rotated. Reed valves control suction and discharge; crossover passages feed refrigerant to both high- and low-service fittings at the rear end of the GM compressor. A gear type of oil pump in the rear head provides for compressor lubrication.

Chrysler Corporation uses Air-Temp compressors of the two-cylinder, "Vee," reciprocating piston type. Ford Motor Company and American Motors use compressors of the two-cylinder, "in-line" type. Late model Fords are equipped with a 10-cylinder unit. (See fig. 14-31.) Most independent (hang on type) air-conditioning systems make use of compressors of the reciprocating piston design.

The most conventional crankshaft type of compressors are two-cycle, two-cylinder units. Reed valves generally are used to control the intake and exhaust of the refrigerant gas during the pumping operation. Older models were lubricated by an oil pump fitted into the reed head. Later models made use of a positive-pressure lubrication system which uses the difference in pressure at the suction intake and pressure in the crankcase, plus centrifugal force.

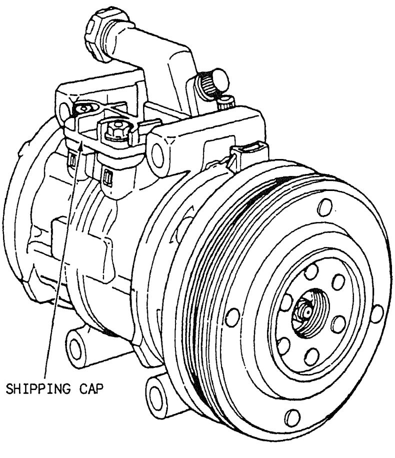
Chrysler Air-Temp units also use the familiar reciprocating piston arrangement and incorporate a rotor type of oil pump in the rear cover plate. These compressors also contain a control valve under the low-side fitting to regulate refrigerant flow through the evaporator to prevent icing of the evaporator core.

Compressor Service Valves

Compressor service valves are built into some systems. They serve as a point of attachment for test gauges or servicing hoses. The service valves have three position controls: front seated, mid-position, and back seated. (See fig. 14-32.)

The position of this double-faced valve is controlled by rotating the valve stem with a service valve wrench. Clockwise rotation seats the front face of the valve and shuts off all refrigerant flow in the system. This position isolates the compressor from the rest of the system.

Counterclockwise rotation unseats the valve and opens the system to refrigerant flow



Reprinted with Ford Motor Company's permission by Wendell C. White.

54.628X

Figure 14-31.—Ten-cylinder compressor.

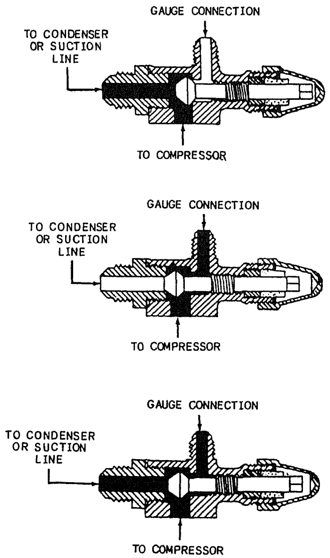


Figure 14-32.—Three-way service valve positions.

(midposition). Systematic checks are performed with a manifold gauge set with the service valve in midposition.

Further counterclockwise rotation of the valve stem seats the rear face of the valve. This position opens the system to the flow of refrigerant but shuts off refrigerant to the test connector. The service valves are used for testing pressure; for isolating the compressor for repair or replacement; and for discharging, evacuating, and charging the system.

Instead of service valves, many modern compressors have "Schrader" or "Dill" service connectors or gauge port fittings. Special test hoses are available to fit these connectors, or adapters can be used with standard test hoses. These valves are similar to a valve core on a valve stem of a tire. A special hose or adapter is used with these valves.

Compressors used in automotive air-conditioning systems generally are equipped with an electromagnetic clutch which energizes and de-energizes to engage and disengage the compressor. Two types of clutches are in general use: the rotating coil and the stationary coil.

The rotating coil clutch has a magnetic coil mounted in the pulley which rotates with the pulley. It operates electrically through connections to a stationary brush assembly and rotating slip rings. The clutch permits the compressor to engage or disengage as required for adequate air conditioning. The stationary coil clutch has the magnetic coil mounted on the end of the compressor. Electrical connections are made directly to the coil leads.

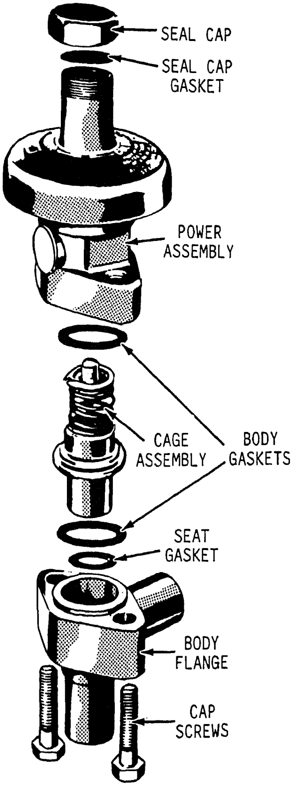
The belt-driven pulley is always in rotation while the engine is running. The compressor is in rotation and operation only when the clutch engages it to the pulley.

Air-conditioning and refrigeration systems use various control devices, including those for the refrigerant, the capillary tube usually found on window units, the automatic expansion valves also found on window units and small package units, the thermal expansion valve, and various types of suction pressure-regulating valves and devices. A brief description of a suction pressure-regulating valve is given below. A suction pressure-regulating valve is used on automotive air conditioning because the varying rpm of the compressor unit must maintain a constant pressure in the evaporator.

Suction Pressure-Regulating Valves

Suction pressure-regulating valves may be installed in the suction line at the outlet of the evaporator when a minimum temperature must be maintained.

Suction pressure-regulating valves decrease the temperature difference which would otherwise exist between the compartment temperature and the surface of the cooling coils. The amount of heat that can be transferred into the evaporating refrigerant is directly proportional to the temperature difference. Figure 14-33 shows an



87.70

Figure 14-33.—Exploded view of typical suction pressure-regulating valve.

exploded view of a typical suction pressure-regulating valve, sometimes called a suction throttling valve, in automotive air conditioners.

General Motors has developed an air-conditioning system in which a valves-in-receiver (VIR) unit performs the functions of the receiver drier, thermostatic expansion valve, sight glass, and POA (pilot-operated absolute) suction throttling valve.

The VIR assembly is mounted next to the evaporator which eliminates the need for an external equalizer line between the thermostatic expansion valve and the outlet of the POA suction throttling valve. The equalizer function is carried out by a drilled hole (equalizer port) between the two valve cavities in the VIR housing.

The thermostatic expansion valve is also eliminated. The diaphragm of the VIR expansion valve is exposed to the refrigerant vapor entering the VIR unit from the outlet of the evaporator. The sight glass is in the valve housing at the inlet end of the thermostatic valve cavity, where it gives a liquid indication of the refrigerant level.

The VIR thermostatic expansion valve controls the flow of refrigerant to the evaporator by sensing the temperature and pressure of the refrigerant gas as it passes through the VIR unit on its way to the compressor. The POA suction throttling valve controls the flow of refrigerant from the evaporator to maintain a constant evaporator pressure of 30 psi. These are a capsule type of valve. When found to be defective, the complete valve capsule must be replaced.

The drier desiccant is in a bag in the receiver shell. It is replaceable by removing the shell and removing the old bag and installing a new bag of desiccant.

Service procedures for the VIR system differ in some respect from the service procedures performed on conventional automotive air-conditioning systems.

The complete VIR unit should be removed when parts are replaced. GM also recommends that the desiccant bag be replaced anytime the VIR unit is removed for valve service.

Discharging, evacuating, and charging procedures for the VIR system are similar to those used when servicing conventional air-conditioning systems. However, the hookup of the manifold gauge set is to the VIR unit. The high-pressure fitting is located in the VIR inlet line. The low-pressure fitting is located in the VIR unit.

SERVICE PRECAUTIONS

Observe the following precautions whenever you are tasked to service air-conditioning equipment.

1. Never open or loosen a connection before discharging the system.
2. When loosening a connection, if any residual pressure is evident, allow it to leak off before opening the fitting.
3. A system that has been opened to replace a component or one which has discharged through leakage must be evacuated before charging.
4. Immediately after disconnecting a component from the system, seal the open fittings with a cap or plug.
5. Before disconnecting a component from the system, clean the outside of the fittings thoroughly.
6. Do not remove the sealing caps from a replacement component until you are ready to install it.
7. Refrigerant oil absorbs moisture from the atmosphere if it is left uncapped. Do not open an oil container until it is ready to use, and install the cap immediately after using. Store the oil only in a clean, moisture-free container.
8. Before connecting an open fitting, always install a new seal ring. Coat the fitting and seal with the refrigerant oil before connecting.
9. When installing a refrigerant line, avoid sharp bends. Position the line away from the exhaust or any sharp edges that may chafe the line.
10. Tighten the fittings only to specified torque. The copper and aluminum fittings that are used in refrigerant systems will not tolerate overtightening.
11. When disconnecting a fitting, use a wrench on both halves of the fitting to prevent twisting of refrigerant lines or tubes.
12. Do not open a refrigerant system or uncap a replacement component unless it is as close as possible to room temperature. This prevents condensation from forming inside a component that is cooler than the surrounding air.
13. Keep the service tools and work area clean. Contamination of a refrigerant system through careless work habits must be avoided.

DIAGNOSIS AND TESTING

Diagnosis is more than just following a series of interrelated steps to find the solution to a

specific condition. It is a way of looking at systems that are not functioning the way they should and finding out why. Also, it is knowing how the system should work, and whether it is working correctly. All good diagnosticians use the same basic procedures.

There are basic rules for diagnosis. If these rules are followed, the cause of the condition will usually be found the first time through the system.

Know the system; know how the parts go together. Also, know how the system operates and its limits, and what happens when something goes wrong. Sometimes this means comparing a system that is working properly with the one you are servicing.

Know the history of the system. How old or new is the system? What kind of treatment has it had? Has it been serviced in the past in such a manner that might relate to the present condition? What is the service history? A clue in any of these areas might save a lot of diagnosis time.

Know the probability of certain conditions developing. It is true that most conditions are caused by simple things rather than by complex ones, and they occur in a fairly predictable pattern. Electrical problem conditions, for instance, usually occur at connections rather than in components. An engine "no-start" is more likely to be caused by a loose wire or some component out of adjustment than a sheared off camshaft. Know the difference between impossible and improbable. Many good technicians have spent hours diagnosing a system because they thought certain failures were "impossible," only to eventually find out the failures were just "improbable" and actually had happened. Remember, new parts are just that—new. It does not mean they are good functioning parts.

Don't cure the symptom and leave the cause. Recharging a refrigerant system may correct the condition of insufficient cooling, but it does not correct the original problem unless a cause is found. A properly working system does not lose refrigerant over time.

Be sure the cause is found; do not be fooled into thinking the cause of the problem has been found. Perform the proper tests, then double-check the results. The system should have been checked for refrigerant leaks. If no leaks were found, perform a leak test with the system under extremely high pressure. If the system performed properly when new, it had to have a leak to be low in charge.

No matter what form charts may take, they are simply a way of expressing the relationship between the basic logic and a physical system of components. It is a way of determining the cause of a condition in the shortest possible amount of time. Diagnosis charts combine many areas of diagnosis into one visual display. This will help you to make determinations, such as the following:

- Probability of certain things occurring in a system
- Speed of checking certain components, or functions, before others
- Simplicity of performing certain tests before others
- Elimination of checking huge sections of a system by performing simple tests
- Certainty of narrowing down the search to a small area before performing in-depth testing

The fastest way to find a condition is to work with the tools that are available, which means working with proven diagnosis charts and the proper special tools for the system being worked on.

SYSTEM VISUAL INSPECTION

It is often possible to detect problem causes by a careful visual inspection of the air-conditioning refrigerant system. This includes broken belts, obstructed condenser air passages, a loose clutch, loose or broken mounting brackets, disconnected or broken wires, and refrigerant leaks.

A refrigerant leak usually appears as an oily residue at the leakage point in the system. The oily residue soon picks up dust or dirt particles from the surrounding air and appears greasy. Through time, this builds up and appears to be a heavy, dirt-impregnated grease.

Most common leaks are caused by damaged or missing O-ring seals at the various hose and component connections. When these O rings are replaced, the new O rings should be lubricated with refrigerant oil. Care should be taken to keep lint from shop towels or cloths from contaminating the internal surfaces of the connection. Leakage may occur at a spring lock

Refrigerant	Vaporizes °C(°F)[1]	Approximate Closed Container Pressure[1] kPa (psi)[2] 15.57°C (60°F)	21.13°C (70°F)	26.69°C (80°F)	32.25°C (90°F)	37.81°C (100°F)	Adaptability
R-12	−29.80 (−21.6)	393 (57)	483 (70)	579 (84)	689 (100)	807 (117)	Self Propelling
F-114	3.56 (38.4)	55.16 (8)	89.63 (13)	131 (19)	172 (25)	221 (32)	
F-11[3]	23.74 (74.7)	27 (8 in Hg)	10 (3 in Hg)	7 (1)	34 (5)	62 (9)	
F-113	47.59 (117.6)	74 (22 in Hg)	64 (19 in Hg)	54 (16 in Hg)	44 (13 in Hg)	27 (8 in Hg)	Pump Required

[1]At sea level atmospheric pressure.
[2]kPa (psi) unless otherwise noted.
[3]F-11 is also available in pressurized containers. This makes it suitable for usage when special flushing equipment is not available. However, it is more toxic than R-12 and F-114.

Reprinted with Ford Motor Company's permission by Wendell C. White.

54.X

Figure 14-34.—Refrigerant flushing information chart.

coupling if the wrong O rings are used at the coupling.

Another type of leak may appear at the internal Schrader-type air-conditioning charging valve core in the service gauge port valve fittings. If tightening the valve core does not stop the leak, it should be replaced with a new air-conditioning charging valve core.

Missing service gauge port valve caps can also cause a refrigerant leak. If this important primary seal (the valve cap) is missing, dirt enters the area of the air-conditioning charging valve core. When the service hose is attached, the valve depressor in the end of the service hose forces the dirt into the valve seat area, and it destroys the sealing surface of the air-conditioning charging valve core. When a service gauge port valve cap is missing, the protected area of the air-conditioning charging valve core should be cleaned and a new service gauge port valve cap should be installed.

CAUTION: Service gauge port valve cap must be installed finger tight. If tightened with pliers, the sealing surface of the service gauge port valve may be damaged.

CLEANING A BADLY CONTAMINATED REFRIGERANT SYSTEM

A refrigerant system can become badly contaminated for a number of reasons.

- The compressor may have failed due to damage or wear.
- The compressor may have been run for some time with a severe leak or an opening in the system.
- The system may have been damaged by a collision and left open for some time.
- The system may not have been cleaned properly after a previous failure.
- The system may have been operated for a time with water or moisture in it.

A badly contaminated system contains water, carbon, and other decomposition products. When such a condition exists, the system must be flushed with a special flushing agent, using equipment designed especially for this purpose. Follow the suggestions and procedures outlined for proper cleaning.

Flushing Agents

A refrigerant, to be suitable as a flushing agent, must remain in the liquid state during the flushing operation to wash the inside surfaces of the system components. Refrigerant vapor will not remove contaminant particles. They must be flushed with a liquid. Some refrigerants are better suited for this purpose than others (fig. 14-34).

The chart (fig. 14-34) reflects pressure/ temperature relationship and the vaporization temperature for four refrigerants. Neither R-12 nor R-114 is suitable for flushing a system because

of low vaporization (boiling) points— −21.6 °F for R-12 and 38.4 °F for R-114. Both of these refrigerants are difficult to use and would not do a sufficient job because of the tendency to vaporize rather than remain in a liquid state, especially in high-ambient temperatures.

The two remaining refrigerants listed in the chart (R-11 and R-113) are much better suited for use with special flushing equipment. Both have rather high vaporization points—74.7 °F for R-11 and 117.6 °F for R-113. Both refrigerants also have low closed-container pressures. This reduces the danger of an accidental system discharge to a ruptured hose or fitting. R-113 will do the best job and is recommended as a flushing refrigerant. Both R-11 and R-113 require a propellant or a pump type of flushing equipment due to their low closed-container pressures. R-12 can be used as a propellant with either flushing refrigerant. R-11 is available in pressurized containers. Although not recommended for regular use, it may become necessary to use R-11 if special flushing equipment is not available. It is more toxic than other refrigerants, and it should be handled with extra care.

CAUTION: Use extreme care and adhere to all safety precautions related to the use of refrigerants when flushing a system.

System Cleaning and Flushing

When it is necessary to flush a refrigerant system, the suction accumulator/drier must be removed and replaced, as it is impossible to clean. Remove the fixed orifice tube. If a new tube is available, replace the contaminated one; otherwise, wash it carefully in flushing refrigerant or mineral spirits and blow it dry. If it does not show signs of damage or deterioration, it may be reused. Install new O rings.

Any moisture in the evaporator will be removed during leak testing and system evacuation following the cleaning job. Perform each step of the cleaning procedure carefully as outlined below.

1. Check the hose connections at the flushing cylinder outlet and flushing nozzle to ensure they are secure.
2. Ensure the flushing cylinder is filled with approximately 1 pint of R-113 and that the valve assembly on top of the cylinder is tightened securely.
3. Connect a can of R-12 to the Schrader valve at the top of the charging cylinder. A refrigerant hose and a special, safety type of refrigerant dispensing valve are required for connecting the small can to the cylinder. Ensure all connections are secure.
4. Connect a gauge manifold and a discharge system. Disconnect the gauge manifold.
5. Remove and discard the suction accumulator/drier. Install a new accumulator/drier and connect it to the evaporator. Do not connect it to the suction line from the compressor. Ensure a protective cap is in place on the suction line connection.
6. Replace the fixed orifice tube. Install a protective cap on the evaporator inlet tube as soon as the new orifice tube is in place. The liquid line will be connected later.
7. Remove the compressor from the vehicle for cleaning and servicing or replacement, whichever is required. If the compressor is cleaned and serviced, add the specified amount of refrigerant oil before installing it on the mounting brackets in the vehicle. Install the shipping caps on the compressor connections. Install a new compressor on the mounting brackets in the vehicle.
8. Back flush the condenser and the liquid line as follows:
   a. Remove two O rings from the condenser inlet tube spring lock coupling.
   b. Remove the discharge hose from the condenser and clamp a piece of (1/2-inch I.D.) heater hose to the condenser inlet line. Ensure the hose is long enough to insert the free end into a suitable waste container to catch the flushing refrigerant.
   c. Move the flushing equipment into position and open the valve on the can of R-12 (fully counterclockwise).
   d. Back flush the condenser and the liquid line by introducing flushing refrigerant into the supported end of the liquid line with the flushing nozzle. Hold the nozzle firmly against the open end of the liquid line.
   e. After the liquid line and condenser have been flushed, lay the charging cylinder on its side so R-12 will not force more of the flushing refrigerant into the liquid line. Press the nozzle firmly to the liquid line and admit the R-12 to force all of the flushing refrigerant from the liquid line and condenser.
   f. Remove the 1/2-inch hose and clamp from the condenser inlet connection.

g. Stand the flushing cylinder upright and flush the compressor discharge hose. Secure it so the flushing refrigerant goes into the waste container.

h. Close the dispensing valve of the R-12 can (fully clockwise). If there is any flushing refrigerant in the cylinder, it may be left there until the next flushing job. Put the flushing kit and R-12 can in a suitable storage location.

i. Install the new lubricated O rings on the spring lock coupling male fittings on both the condenser inlet and the liquid lines. Assemble the couplings.

9. Connect all refrigerant lines. All connections should be cleaned and new O rings should be used. Lubricate new O rings with clean refrigerant oil.

10. Connect a charging station or manifold gauge set and charge the system with 1 pound of R-12. (Do not evacuate the system until after it has been leak tested.)

11. Leak test all connections and components with a flame type of leak detector or an electronic leak detector. If no leaks are found, go to Step 12. If leaks are found, service as necessary; check the system and then go to Step 12.

12. Evacuate and charge the system with a specified amount of R-12. Operate the system to ensure it is cooling properly.

SAFETY PRECAUTIONS

The refrigerant used in the air-conditioning system is R-12. R-12 is nonexplosive, nonflammable, noncorrosive, has practically no odor, and is heavier than air. Although it is classified as a safe refrigerant, certain precautions must be observed to protect the parts involved and the person working on the unit. Liquid R-12 at normal atmospheric pressure and temperature evaporates so quickly that it has the tendency to freeze anything it contacts. For this reason, extreme care must be taken to prevent any liquid refrigerant from coming in contact with the skin and especially the eyes.

R-12 is readily absorbed by most types of oil. For this reason, a bottle of sterile mineral oil and a quantity of weak boric acid solution must always be kept nearby when servicing the air-conditioning system. Should any liquid refrigerant get into your eyes, immediately use a few drops of mineral oil to wash them out, then wash the eyes clean with the weak boric acid solution. Seek a doctor's aid immediately even though irritation may have ceased. Always wear safety goggles when servicing any part of the refrigerant system. The R-12 in the system is always under pressure. Because the system is tightly sealed, heat applied to any part could cause this pressure to build up excessively.

To avoid a dangerous explosion, never weld, use a blow torch, solder, steam clean, bake body finishes, or use any excessive amount of heat on or in the immediate area of any part of the refrigerant system or refrigerant supply tank, while they are closed to the atmosphere, whether filled with refrigerant or not.

The liquid refrigerant evaporates so rapidly that the resulting refrigerant gas displaces the air surrounding the area where the refrigerant is released. To prevent possible suffocation in enclosed areas, always discharge the refrigerant from the refrigerant system into the garage exhaust collector. Always maintain good ventilation surrounding the work area.

Although R-12 gas, under normal conditions, is nonpoisonous, the discharge of refrigerant gas near an open flame can produce a very poisonous gas. This gas also attacks all bright metal surfaces. This poisonous gas is generated when the flame type of leak detector is used. Avoid inhaling the fumes from the leak detector. Ensure that R-12 is both stored and installed according to all state and local ordinances.

When admitting R-12 gas into the cooling unit, always keep the tank in an upright position. If the tank is on its side or upside down, liquid R-12 enters the system and may damage the compressor.

TRUCK AND BUS AIR CONDITIONING

The cabs of many truck-tractors and long distance hauling trucks and earthmover cabs are air-conditioned. Most of this equipment is of the "hang on" type and is installed after the cab has been made.

Some truck air-conditioning units have two evaporators: one for the cab and one for the relief driver's quarters back of the driver. Some systems use a remote condenser, mounted on the roof of the cab. This type of installation removes the condenser from in front of the radiator, so the radiator can operate at full efficiency. This is especially important during long pulls in low gear.

The system is similar to the automobile air conditioner and is installed and serviced in the same general way.

The air conditioning of buses has progressed rapidly. Because of the large size of the unit, most bus air-conditioning systems use a separate gasoline engine with an automatic starting device to drive the compressor. The system is standard in construction, except for the condensing unit. It is made as compact as possible and generally is installed in the bus, so it can be easily reached for servicing.

Condensing units are often mounted on rails with flexible suction and liquid lines to permit sliding the condensing unit out of the bus body to aid in servicing.

Air-cooled condensers are used. Thermostatic expansion valve refrigerant controls are standard. Finned blower evaporators are also used.

The duct system usually runs between a false ceiling and the roof of the bus. The ducts, usually one on each side of the bus, have grilles at the passenger seats. Grille opening and closing may be controlled by the passengers.

REFERENCES

Trane Air-Conditioning Manual, The Trane Co., La Crosse, Wisc., 1988.

Unit Information Service Manual, 1980 ed., Lennox Industries Inc., Dallas, Tex., 1980.

Air-conditioning Basic Theory (Section 36-31), Tempo/Topaz, Escort Service Manual, Ford Motor Co., Dearborn, Mich., 1987.

Air-conditioning and Refrigerant System (Section 36-32), Tempo/Topaz, Escort Service Manual, Ford Motor Co., Dearborn, Mich., 1987.

APPENDIX I

GLOSSARY

ABSOLUTE ZERO—The point where all molecular motion ceases, −460 °F.

ACCIDENT—A mishap.

AFTERCOOLER—A device which cools the final discharge from a compressor.

ANGLE—A figure formed by two lines or planes extending from, or diverging at, the same point.

ANGLE VALVE—A stop valve that is actually a combination valve and elbow since its outlet branch is at right angles to its inlet branch.

ARC—A portion of the circumference of a circle.

ASCERTAIN—To find out by trial or examination; to determine with certainty.

AZEOTROPIC REFRIGERANT—The liquid mixtures of refrigerants which exhibit a constant maximum and minimum boiling temperature.

BACK-PRESSURE VALVE—A valve similar in design to a low-pressure valve that is capable of opening independently of the pressure, thereby giving free exhaust.

BACK SIPHONAGE—The flowing back of contaminated or polluted water from a plumbing fixture or cross-connection into a water-supply line due to a lowering of the pressure in the line.

BACTERIA—Bacteria are living organisms, microscopic in size, which consist of a single cell. Most bacteria use organic matter for their food and produce waste products as a result of their life processes.

BILL OF MATERIAL—A list of all material required to complete an installation based on takeoffs and estimates.

BLUEPRINT—A photographic print consisting of white lines on a blue background. It is used for copying architect's plans, drawings, and so forth.

BOILER—An enclosed vessel which converts water to steam of proper temperature and pressure for an intended purpose.

BOILER SETTING—The structure that encloses a boiler and forms the furnace.

BOILING POINT—The temperature at which a liquid boils at a given pressure; that is, H_2O BP = 212 °F or 100 °C at sea level.

BONNET—A cover used to guide and enclose the tail end of a valve spindle.

BTU—British thermal unit.

CAPILLARY TUBE—A tube having a small internal and external diameter. It is sometimes referred to as a restrictor tube. Capillary tubes are used between the bulb and power element of thermostatic expansion valves and remote bulb temperature controllers.

CATHODIC PROTECTION—The use of material and liquid to cause electricity to flow to avoid corrosion.

CBMU—Construction Battalion Maintenance Unit.

CBU—Construction Battalion Unit.

CEC—Civil Engineer Corps.

CENTIGRADE—A thermometer scale in which 0 degrees represents the freezing point and 100 degrees represents the boiling point of water at a pressure of 1 atmosphere. Generally used with metric units of measure.

CENTRIFUGAL FORCE—The force that impels a substance to move outward from the center of rotation.

CHECK VALVE—An automatic nonreturn valve or a valve which permits a fluid to pass in one direction but automatically closes if the fluid begins to pass in the opposite direction.

CHLORINATION—The disinfection of a substance by a chlorine chemical.

CHLORINE—A powerful disinfectant, used extensively in water treatment. As a gas, its color is greenish yellow, and it is about 2 1/2 times heavier than air. As a liquid, its color is amber, and it is about 1 1/2 times heavier than water. It is toxic to all organisms and corrosive (in the presence of water) to most metals.

CIRCLE—A plane figure having every point on its circumference (perimeter) equidistant from the center.

CLARIFICATION OF WATER—The removal of suspended materials to produce a clear, clean liquid.

CLEANOUT—A fitting installed in waste lines to permit removal of stoppages.

COAGULANTS—The chemicals added to destabilize, to aggregate, and to bind together colloids and emulsions to improve settleability, filterability, or drainability.

COLIFORM—The coliform groups of organisms are a bacterial indicator of contamination. This group has as one of its primary habitats the intestinal tract of human beings. Coliforms also may be found in the intestinal tract of warm-blooded animals and in plants, soil, air, and the aquatic environment.

COMCBLANT—Commander, Construction Battalions Atlantic.

COMCBPAC—Commander, Construction Battalions Pacific.

COMPRESSOR—A machine designed to pump gas from a low-pressure space to a high-pressure space.

CONDENSATION—The process of changing a vapor to a liquid.

CONDENSER—A component in a refrigeration system which removes and dissipates heat from a compressed refrigerant.

CONDUCTION—The transmission of heat from one substance or part to another substance or part which are in direct contact with each other.

CONSTRUCTION LINES—The lightly drawn lines used in the preliminary layout of a drawing.

CONTROL—The regulation of system equipment to maintain the conditions desired.

CONVECTION—The transfer of heat by means of mediums, such as water, air, and steam.

COOLING TOWER—A device for cooling water by evaporation in air. The water is usually sprayed into an airstream where part of the water evaporates, thus reducing the temperature of the remaining water.

COPPERS—The steam-jacketed kettles sized from 20 to 80 gallons used in the peparation of food.

CROSS-CONNECTION—In plumbing, a physical connection through which a supply of potable water could be contaminated, polluted, or infected. A physical connection between a potable water supply and one of questionable origin.

CSR—Central storeroom.

CTR—Central tool room.

DC—Direct current.

DEGREE OF TEMPERATURE—The measurement of heat intensity.

DEHYDRATOR—A device that contains a desiccant for the purpose of removing moisture from the refrigerant.

DHW—Domestic hot-water system.

DIATOMACEOUS EARTH—A porous mineral powder, used as a filtering medium for the removal of suspended materials.

DIFFERENTIATE—To distinguish; to alter; to make different by modification as a biological species.

DIRECT LABOR—All labor that contributes directly to construction tasks.

DISCHARGE HEAD—The pressure of a liquid as it leaves the discharge side of a pump.

DISINFECTION—The chemical destruction of bacteria.

EVAPORATION—The process of converting a liquid substance into a vapor or a change of state.

EVAPORATOR—A component of a refrigeration system which permits the absorption of heat from a desired medium or space.

EXPANSION VALVE—A valve designed to meter the flow of liquid refrigerant to an evaporator.

FILTRATION—The process of removing organisms, turbidity, iron, color, taste, and odor during the water treatment process.

FLASH POINT—The temperature at which a substance gives off enough vapor to support combustion (ignition temperature).

GATE VALVE—A sluice with two inclined seats between which the valve wedges down in closing. The passage through the valve is in an uninterrupted line, and when the valve is opened, the sluice is drawn up into a dome or recess, leaving an unobstructed passage the full diameter of the pipe.

GLOBE VALVE—A valve with a round, ball-like shell, that is used for regulating or controlling the flow of gases or steam.

GPD—Gallons per day.

GPH—Gallons per hour.

GPM—Gallons per minute.

HALIDE TORCH—A device used to detect refrigerant leaks in a refrigeration system. A burner equipped with a source of fuel, a mixing chamber, a reactor plate, and an exploring tube. The reactor plate surrounds the flame.

HEAD—The increase in pressure resulting from the addition of energy to a liquid by a pump.

HEAT—The energy that is measured in British thermal units.

HEAT OF VAPOR—The heat content of the gas, or the heat necessary to raise the temperature of a liquid from a predetermined level to the boiling temperature plus the latent heat of vaporization necessary to convert the liquid to a gas.

HERMETICALLY SEALED—Caused to be airtight.

HTHW—High-temperature hot-water system.

HUMIDITY—The amount of water vapor in a given volume of air.

INDIRECT LABOR—Labor that supports construction operations but does not produce an end product by itself.

INTERCOOLER—A device which cools compressed gases between stages in a compressor.

ISOMETRIC DRAWING—A drawing that visualizes a three-dimensional picture in one drawing.

JOINING—All the procedures used to connect pipes together.

LATENT HEAT—The amount of heat required to change the state of a substance without a measurable change in temperature.

LEGEND—A description of any special or unusual marks, symbols, or line connections used in a drawing.

MAIN SOIL AND WASTE VENT—The portion of the waste stack which extends above the highest fixture branch.

MATERIAL TAKEOFF—The estimate of materials required for a job based on plans and specifications.

MECHANICAL PLANS—All layouts and details for systems of plumbing, heating, ventilating, air conditioning, and refrigeration.

MISHAP—An accident.

MLO—Material Liaison Office.

MULTISTAGE PUMP—A pump having two or more devices for imparting a moving force upon a liquid.

NAVFAC—Naval Facilities Engineering Command.

NCR—Naval Construction Regiment.

NCTC—Naval Construction Training Center.

NET POSITIVE SUCTION HEAD (NPSH)—Pump suction pressure minus vapor pressure expressed in feet of liquid at the pump suction.

NMCB—Naval Mobile Construction Battalion.

NOTES—Descriptive writing on a drawing to give verbal instructions or additional information.

NRTC—Nonresident training course.

OBA—Oxygen-breathing apparatus.

OCCSTDS—Occupational standards.

OVERHEAD LABOR—All labor which must be performed, regardless of the assigned mission.

P-TRAP—A type of fixture trap.

PACKING—The materials used to seal moving machinery joints against leakage.

POSTCHLORINATION—Disinfection after filtration.

POTABLE WATER—Water suitable for drinking, cooking, and personal use.

PPM—Parts per million.

PRECHLORINATION—Disinfection before filtration.

PREVENTIVE—Serving to prevent or hinder; a precautionary agent or measure.

PRODUCTIVE LABOR—All direct and indirect labor totaled together.

PSIG—Pounds per square inch gauge.

PUMP—A mechanical device that applies force to move any substance which flows or can be made to flow.

PUMP FLUID END—The points where fluid enters or discharges from a pump.

PUMP POWER END—The point at which the prime mover drive system attaches to a pump.

PURGE—The discharging of impurities and noncondensable gases to the atmosphere.

R-12—Dichlorodifluoromethane (CCl_2F_2) refrigerant.

R-22—Monochlorodifluoromethane ($CHClF_2$) refrigerant.

R-717—Ammonia (NH_3) refrigerant.

RADIATION—The transfer of heat through space by heat waves.

RADIUS—A straight line from the center of a circle or sphere to its circumference or surface.

RECEIVER—A vessel for storing the refrigerant liquefied by the condenser.

REDUCING VALVE—A spring-loaded or lever-loaded valve similar to a safety valve, designed to maintain a lower-end constant pressure beyond the valve.

REHABILITATE—To restore to a former capacity or position.

RELATIVE HUMIDITY—The percentage of water vapor in the air when compared to the amount it does hold as to the amount it could hold.

ROUGHING IN—The installation of all parts of a plumbing system; completed before installation of fixtures.

SCAFFOLD—A temporary structure for holding workers and materials during the erection, repair, or decoration of a building.

SENSIBLE HEAT—The heat that can be measured in degrees of temperature with a thermometer.

SHELL AND TUBE—A designation for heat exchangers, condensers, and chillers, consisting of a tube bundle within a shell or casing.

SHORING—To support or batter the sides of trenches in all but hard rock.

SIGHT GLASS, LIQUID—A glass "bull's-eye" installed in the liquid line permitting visual inspection of the liquid refrigerant. Primarily for the purpose of detecting bubbles in the liquid indicating the shortage of refrigerant in the system.

SINGLE-STAGE PUMP—A pump having one device for imparting a moving force upon a liquid.

SITUATION—The way in which something is placed in relation to its surroundings.

SPECIFIC HEAT—The quantity of heat expressed in Btu required to raise 1 pound of any substance 1 °F in temperature.

SPECIFICATIONS—The statements which specify types and quality of materials and installation methods.

STEAM CHEST—A pressure cooker in the galley.

SUCTION HEAD—The total pressure of a liquid entering a pump.

SUPERHEAT—The temperature increase above the saturation temperature or above the boiling point.

SUPERVISE—To oversee in order to direct, as employees.

SYMBOL—The stylized graphical representation of commonly used component parts shown in a drawing.

THERMOSTAT—A device for controlling equipment in response to temperature change. A temperature-sensitive controller.

TON OF REFRIGERATION—A unit of refrigeration capacity corresponding to the removal of 200 Btu per minute, 12,000 Btu per hour, or 288,000 Btu per day. It is so named because it is equivalent in cooling effect to melting 1 ton of ice in 24 hours.

TOTAL DISCHARGE HEAD—The difference between the suction head and discharge head of a pump.

TOTAL HEAT—Sensible heat plus latent heat. Expressed in Btu.

TRAMAN—Training manual.

TRAP SEAL—The water held in the bend of a fixture trap.

UNLOADERS—A system for removing all but friction loads from a compressor.

VACUUM—A reduction in pressure below atmospheric pressure. Usually stated in inches of mercury.

VACUUM PUMP—A pump for exhausting a system. A pump designed to produce a vacuum in a closed system or vessel.

VALVE—A device for regulating, stopping, or starting flow in a system, and for controlling direction of flow. The design that allows an opening to the full diameter of the pipe is known as a gate valve. A valve that controls direction is known as a check valve. The basic difference between a cock and a valve is a cock is usually closed by manipulating a tapered plug having ports or holes that correspond to ports in the valve body.

VALVE BOX—A pipe over a valve stem or wheel, capped to exclude dirt that might interfere with valve operation but permits access to the valve stem for opening or closing purposes.

VALVE SEAT—A flat or conical fixed surface on which a valve rests, or against which it presses.

VALVE STEM—A rod or spindle attached to a valve and used to move the valve.

VAPORIZATION—The process of changing a liquid to a vapor.

VENT—A piping system which prevents siphonage of the trap seal by equalizing the pressure on the outlet side of a trap with the inlet side.

VISCOSITY—The ease or difficulty with which a liquid flows.

APPENDIX II

CONVERSION TABLES

MULTIPLY	BY	TO OBTAIN
Acres	43,560	square feet
Acres	4047	square meters
Acres	1.562×10^{-3}	square miles
Acres	5645.38	square yards
Acres	4840	square yards
Board-feet	0.2530	cubic inches
British thermal units	144 sq. in. × 1 in.	kilogram-calories
British thermal units	777.5	foot-pounds
British thermal units	3.927×10^{-4}	horsepower-hours
British thermal units	1054	joules
British thermal units	107.5	kilogram-meters
British thermal units	2.928×10^{-4}	kilowatt-hours
Btu per min	12.96	foot-pounds per sec
Btu per min	0.2356	horsepower
Btu per min	0.01757	kilowatts
Btu per min	17.57	watts
Btu per sq ft per min	0.1220	watts per square inch
Centiliters	0.01	liters
Centimeters	0.3937	inches
Centimeters	0.01	meters
Centimeters	393.7	mils
Centimeters	10	millimeters
Cubic centimeters	3.531×10^{-3}	cubic feet
Cubic centimeters	6.102×10^{-2}	cubic inches
Cubic centimeters	10^{-6}	Cubic meters
Cubic centimeters	1.306×10^{-6}	cubic yards
Cubic centimeters	2.642×10^{-4}	gallons
Cubic centimeters	10^{-2}	liters
Cubic centimeters	2.113×10^{-3}	pints (liq)
Cubic centimeters	1.057×10^{-3}	quarts (liq)
Cubic feet	2.832×10^{6}	cubic cms
Cubic feet	1728	cubic inches
Cubic feet	0.02832	cubic meters
Cubic feet	0.03704	cubic yards
Cubic feet	7.481	gallons
Cubic feet	28.32	liters
Cubic feet	59.84	pints (liq)
Cubic feet	29.92	quarts (liq)
Cubic feet per minute	472.0	cubic cms per sec
Cubic feet per minute	0.1247	gallons per sec
Cubic feet per minute	0.4720	liters per second
Cubic feet per minute	82.4	lbs of water per min
Cubic inches	16.39	cubic centimeters
Cubic inches	5.787×10^{-4}	cubic feet

MULTIPLY	BY	TO OBTAIN
Cubic inches	1.639×10^{-5}	cubic meters
Cubic inches	2.143×10^{-5}	cubic yards
Cubic inches	4.329×10^{-2}	gallons
Cubic inches	1.639×10^{-2}	liters
Cubic inches	0.03463	pints (liq)
Cubic inches	0.01732	quarts (liq)
Cubic meters	10^{4}	cubic centimeters
Cubic meters	35.31	cubic feet
Cubic meters	81.023	cubic inches
Cubic meters	1.303	cubic yards
Cubic meters	264.2	gallons
Cubic meters	10^{2}	liters
Cubic meters	2113	pints (liq)
Cubic meters	1057	quarts (liq)
Cubic yards	7.646×10^{5}	cubic centimeters
Cubic yards	27	cubic feet
Cubic yards	46.656	cubic inches
Cubic yards	0.7646	cubic meters
Cubic yards	202.0	gallons
Cubic yards	764.6	liters
Cubic yards	1616	pints (liq)
Cubic yards	807.9	quarts (liq)
Cubic yards per minute	0.45	cubic feet per second
Cubic yards per minute	3.367	gallons per second
Cubic yards per minute	12.74	liters per second
Days	24	hours
Days	1440	minutes
Days	86,400	seconds
Fathoms	6	feet
Feet	30.48	centimeters
Feet	12	inches
Feet	0.3048	meters
Feet	.36	yards
Feet	1/3	yards
Feet of water	0.02950	atmospheres
Feet of water	0.8826	inches of mercury
Feet of water	304.8	kgs per square meter
Feet of water	62.43	pounds per sq ft
Feet of water	0.4335	pounds per sq inch
Foot-pounds	1.286×10^{-3}	British thermal units
Foot-pounds	1.356×10^{7}	ergs
Foot-pounds	5.050×10^{-7}	horsepower-hours
Foot-pounds	1.356	joules
Foot-pounds	3.241×10^{-4}	kilogram-calories
Foot-pounds	0.1383	kilogram-meters

MULTIPLY	BY	TO OBTAIN	MULTIPLY	BY	TO OBTAIN
Foot-pounds	3.766×10^{-7}	kilowatt-hours	Kilometers	0.6214	miles
Gallons	3785	cubic centimeters	Kilometers	1093.6	yards
Gallons	0.1337	cubic feet	Kilowatts	56.92	Btu per min
Gallons	231	cubic inches	Kilowatts	4.425×10^{2}	foot-pounds per min
Gallons	3.785×10^{-3}	cubic meters	Kilowatts	737.6	foot-pounds per sec
Gallons	4.951×10^{-3}	cubic yards	Kilowatts	1.341	horsepower
Gallons	3.785	liters	Kilowatts	14.34	kg.-calories per min
Gallons	8	pints (liq)	Kilowatts	10^{3}	watts
Gallons	4	quarts (liq)	Liters	10^{2}	cubic centimeters
Horsepower	42.44	Btu per min	Liters	0.03531	cubic feet
Horsepower	33,000	foot-pounds per min	Liters	61.02	cubic inches
Horsepower	550	foot-pounds per sec	Liters	10^{3}	cubic meters
Horsepower	1.014	horsepower (metric)	Liters	1.308×10^{-2}	cubic yards
Horsepower	10.70	kg.-calories per min	Liters	0.2642	gallons
Horsepower	0.7457	kilowatts	Liters	2.113	pints (liq)
Horsepower	745.7	watts	Liters	1.057	quarts (liq)
Horsepower (boiler)	33.520	Btu per hour	Meters	100	centimeters
Horsepower (boiler)	9.804	kilowatts	Meters	3.2808	feet
Horsepower-hours	2547	British thermal units	Meters	39.37	inches
Horsepower-hours	1.98×10^{4}	foot-pounds	Meters	10^{-3}	kilometers
Horsepower-hours	2.684×10^{4}	joules	Meters	10^{3}	millimeters
Horsepower-hours	641.7	kilogram-calories	Meters	1.0936	yards
Horsepower-hours	2.737×10^{4}	kilogram-meters	Meter-kilograms	9.807×10^{7}	centimeter-dynes
Horsepower-hours	0.7457	kilowatt-hours	Miles	1.609×10^{3}	centimeters
Hours	60	minutes	Miles	5280	feet
Hours	3600	seconds	Miles	1.6093	kilometers
Inches	2.540	centimeters	Miles	1760	yards
Inches	10^{4}	mils	Miles	1609.3	meters
Inches	.03	yards	Ounces	8	drams
Inches of mercury	0.03342	atmospheres	Ounces	437.5	grains
Inches of mercury	1.133	feet of water	Ounces	28.35	grams
Inches of mercury	345.3	kgs per square meter	Ounces	0.0625	pounds
Inches of mercury	70.73	pounds per square ft	Ounces (fluid)	1.805	cubic inches
Inches of mercury	0.4912	pounds per square in	Ounces (fluid)	0.02957	liters
Inches of water	0.002458	atmospheres	Ounces (troy)	480	grains (troy)
Inches of water	0.07355	inches of mercury	Ounces (troy)	31.10	grams
Inches of water	25.40	kgs per square meter	Ounces (troy)	20	pennyweights troy
Inches of water	0.5781	ounces per square in	Ounces (troy)	0.08333	pounds (troy)
Inches of water	5.204	pounds per square ft	Ounces per sq inch	0.0625	pounds per sq inch
Inches of water	0.03613	pounds per square in	Pounds	7000	grains
Joules	9.486×10^{4}	British thermal units	Pounds	453.6	grams
Kilograms	10^{2}	grams	Pounds	16	ounces
Kilograms	70.93	poundals	Pounds	32.17	poundals
Kilograms	2.2046	pounds	Pounds (troy)	0.8229	pounds (av)
Kilograms	1.102×10^{-2}	tons (short)	Pounds of water	0.01602	cubic feet
Kilometers	3281	feet	Pounds of water	27.68	cubic inches
Kilometers	10^{7}	meters	Pounds of water	0.1198	gallons

INDEX

B

I

J

L

M

O

P

Q

R

S

T

U

V

W

☆U.S.GOVERNMENT PRINTING OFFICE:1990-731-068/20007